Fire at the Urban Wildland Interface:

Performance of California Homes and Buildings

Prepared for:
California Department of Forestry and Fire Protection
Attn: Rodney Slaughter, Deputy State Fire Marshal

Prepared by:
Fire Cause Analysis
213 W. Cutting Blvd
Richmond CA 94804
Attn: Joseph Zicherman, Ph.D., SFPE.

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Cover photo Grand Prix Fire, courtesy of CALMAST:

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Executive Summary

The study presented here was conducted by Fire Cause Analysis[1] of Point Richmond, California in response to a request for proposal from the Office of the California State Fire Marshal (OSFM). The findings produced include a comprehensive review of specific fire performance data collected under the auspices of the OSFM after the major wildfires in Southern California in late 2003.

Preparation of this report, presented a unique opportunity to combine three diverse data sets all of which address the fire performance of buildings – particularly homes – built at the Urban Wildlife Interface (UWI) in California. These sets include, first of all the specific data gathered under the auspices of the OSFM in the after-action analysis of these fires which includes for the first time detailed evaluations of literally thousands of structures whose post-fire condition ranged from undamaged to total losses. This incident specific data was complemented by the second data set – general, historical and peer reviewed technical information concerning UWI fire safety issues gathered over approximately the past 50 years. The third component of the data set utilized in this technical report includes results of fire safety engineering and research activities, primarily conducted by the University of California Forest Products Laboratory. These results compliment the site data by providing sound technical evaluations and descriptions of the fire performance of common construction assemblies elements and technology used in buildings found in UWI areas under controlled conditions which can be applied to field performance of similar assemblies. *Prior to carrying out the latter research, virtually all of the information available on the fire performance of such construction assemblies was based either on limited post fire assessments or eyewitness and other anecdotal data*.

Review of these three data sets - post fire assessments, UWI fire safety engineering data and UWI construction element fire performance – has led to the conclusion that *enhancing the survivability and reducing the vulnerability of homes constructed in UWI areas is both feasible and cost effective for the State of California*. Analysis of the data demonstrates that specific, reasonable solutions do exist to the problem of building vulnerability to ignition of specific construction elements commonly used in construction at UWI sites. These elements include window glazing, doors, venting, wall constructions, roof assemblies and appurtenances such as combustible decks and patios.

Application of these standards does not mean that the state will require use of unusual or unavailable construction technologies that matter, construction technologies that lead to the construction of "bunkers" in UWI areas. Rather, the application of these standards will require appropriate use and maintenance of existing technologies.

The volume and quality of the data collected at the Southern California fire sites by OSFM personnel also provided a unique opportunity to conduct statistical analyses to determine the effect of variables such as site conditions and construction details on the survivability of buildings in the sample. From those results inferences were drawn illustrating specific relationships

[1] Fire Cause Analysis is a multidisciplinary fire safety engineering and investigation firm formed in the late 1970s. Its work areas include research and development for public and private sector clients, investigation in forensic evaluation of fire losses and fire safety questions and consulting in litigations associated with fire investigation and fire safety questions.

between construction details and site variables. Those inferences in turn allowed conclusions to be drawn demonstrating that if the techniques described the proposed Urban Wildland Regulations had been utilized in structures involved in the 2003 Southern California Wildland Fires losses would have been dramatically reduced.

This component of the analysis is of great interest and shows great potential for further development in terms of implications of both performance-based design issues and cost-benefit implications. It is however also the initial effort at creating such correlations and the results should be viewed as such. However, the results obtained clearly illustrate the relationship between acceptable construction detailing methodologies and –at least for the future - unacceptable construction detailing for use in areas subject to UWI fire threats.

Adoption and application of the proposed standards should be considered as one important component of a broader mitigation strategy which is needed. That strategy should include enhanced planning activities prior to development, evolution of fuel management techniques and application of new methods to encourage development and maintenance of defensible space through initiatives both by local authorities having jurisdiction and by insurance carriers to assure that buildings constructed in UWI areas are cited and properly maintained.

Acknowledgements

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University of California personnel Drs. Steve Quarles and Frank Beall, provided material assistance and conducted much of the product testing and research cited here. Numerous members of the fire protection community, in particular, Chief Roland Crawford of Loma Linda, Fire Marshal Tonya Harding of the Orinda-Moraga Fire Protection District, and Marin County Fire Marshal Scott Alber, PE also contributed to the report and project team received comments in the subject matter from Mr. Dave Walls of the California State Department of Housing and Community Development.

The project team included Sharon Waterman AIA, and her colleagues at Interactive Resources, Richmond California; Herb Gough of Carter Gough & Co., licensed contractors and cost estimators, Martinez, California; Ben Scott, statistician; Don Perkins, CFI; Ulises Castellon, CPCU; and project researchers Katherine Hutches, Ariane Hurley and Noah Singer.

1. Introduction

In terms of both extent and value of damage caused, the October 2003 wildfires in Southern California were unprecedented. Their effect on the lives of California's citizens, as well as its economic impact on the state, cannot be underestimated.[2,3,4]

As noted in the "Report to the Governor" (Blue Ribbon Fire Commission, April 4, 2004) the effects of these fires extended beyond affected property owners and local communities. Property losses totaled $2.04 billion. From a tactical perspective, massive efforts - with the accompanying allocations of needed resources - were required to suppress these fires with attendant costs in the range of $250 million. The resources needed to control these fires were called in from local, state and Federal agencies often from locations hundreds of miles away.

From a strategic perspective, the after-action reports on these fires highlighted areas in which mitigation efforts need to be made to prevent frequent repetitions of these incidents. Consideration of mitigation strategies is particularly relevant, since the locations of the 2003 fires were varied and not unique or singular in terms of their characteristics as compared to other Urban Wildland Interface [UWI] areas in California. Moreover, as the 2004 wildfire season develops, it is apparent that the 2003 fires have put the State of California on notice that in the absence of mitigation efforts, fires on this scale will become the rule rather than the exception in future years.

The following three factors were found to essentially control the fate of buildings; especially homes built in UWI affected areas:

1. Combustible vegetation
2. Defensible space
3. Building construction features

Other factors such as ecology, available fire-fighting resources, condition of vegetation and terrain were also important. However, in terms of what can be done from planning, design, construction and maintenance perspectives, those listed above were the controlling items.

The Governor's Blue Ribbon Fire Commission included a range of recommendations addressing both firefighting activities and mitigation of hazards such as those listed above in UWI areas. These must be addressed to reduce foreseeable fire hazards, given the increasing high degree of fire risk demonstrated in California – and in similar areas in the US – during the coming years.[5]

The Office of the California State Fire Marshal has been supporting research to assess and improve the fire performance of buildings, especially single family dwellings, constructed in

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2. Three reports provide insight into these fires. "Report to the Governor" (Blue Ribbon Fire Commission, April 4, 2004) provides a dramatic review of the extent of the impact of this catastrophe on our State.
3. Fire tactics are discussed in the report from Mission-Centered Solutions, 2003, "Southern California Firestorm 2003, Report for the Widland Fire Lessons Learned Center", Parker Colorado. Comments at the local level from San Bernardino are also of interest.

4. Urban Wildlife Interface Committee, 2003, "Initial Report of Findings & Recommendations for the Disaster within the City of San Bernardino Caused by the Effects of the Old Fire". Rancho Cucamonga, California.

5. Section 2.3 considers the concepts of Fire Risk and Fire Hazard as addressed in this report.

UWI areas for some years and since the fall, 2003 UWI fires developed additional programs to address the Task Force's recommendations.[6] The results of that work will assist in providing a blueprint for future means to mitigate the increasing threat – in the absence of the application of new mitigation strategies - posed by UWI fires[7]. One such program is the "Technical Study for Code Development"[8]. This new study was created to evaluate the science and technology associated with the fire performance of construction assemblies and features involved in UWI fires to date and to meaningfully apply the results of those evaluations to new regulatory efforts.

The objective of this report is to present the first detailed analysis – *including detailed statistical interpretations* - of data from thousands of sites exposed to fire hazards during the fall 2003 wildfire season and to consider that data in light of enhanced knowledge of the fire performance of specific construction assembly designs found in the at-risk homes.

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6. Summary data on fire mitigation supported in part by the State of California can be found at http://nature.berkeley.edu/~fbeall/firemit.html.

7. See Appendix I for the text of proposed building construction regulations which address fire performance of construction related features of buildings being constructed in UWI areas.

8. Contract: IFB number: 5CA334189 which has provided support for this study.

2. Fires at the Urban Wildland Interface (UWI) in California.

As a consequence of ecology, topography, weather, population growth and patterns of regional development, California has been dealing with a relatively new class of fire problem. This problem is specifically associated with fires occurring in areas that were formerly undeveloped wildland and which have become built up.

Development in UWI areas occurred gradually at first, as single homes or small developments were built and subdivisions occurred, leading to the construction of cabins or vacation homes in remote areas - often near a state highway or popular lake. More recently, and increasingly, this development pattern has evolved into large subdivisions, often including costly homes, community centers, and schools remote from conventional levels of firefighting resources. Unfortunately, projects in UWI areas also frequently lack features found in similar developments constructed in non wildland areas that can provide a higher level of safety from potential fire hazards.

As UWI fire incidents have increased over the last decade, so has the importance of assessing the impact of these fires on populations associated with UWI areas. To this end, several projects have developed estimates for populations within UWI areas and it is interesting for the present project to note similarities and differences in these methods and the estimates which have been developed.

The Spatial Analysis for Conservation and Sustainability Lab (SILVIS), working with the University of Wisconsin at Madison and the USDA Forest Service, has developed a population model based on housing density, since the housing density of an area 'can be a more suitable measure of human presence and influence on the landscape than population density'.[9] They found this to be particularly true in the case of wildfires, as firefighters must protect the residences and wildland, instead of individual occupants.

Housing density data derived from the U.S. Census information for 2000, using the SILVIS group defined interface and intermix areas as areas of housing where vegetation was either sporadic or continuous, respectively. They further identified interface communities as those communities that are within 1.5 miles of wildland vegetation, or approximately the distance that firebrands can be carried from a wildland fire to the roof of a house. Their exact definitions were as follows:

- Interface: Areas that have more than 1 house per 16 hectares[10], less than 50% vegetation, and are within 1.5 miles of an area that is more than 75% vegetated for over 500 hectares.

- Intermix: Areas that have more than 1 house per 16 hectares, and more than 50% vegetation.

Using these two definitions, the SILVIS lab determined that the overall percentage of homes in the United States within the UWI is 36.7%, with 18.8% falling in the region of interface and the other 17.9% in the region of intermix. Further, the percentage of the land within the 48 contiguous states that falls into the UWI is nearly 10%. Of the 48 contiguous states, California

9. "Characteristics and Location of the Wildland-Urban Interface in the United States'; Susan Stewart, Volker Radeloff, and Roger Hammer; Nov 2003, 2nd International Wildland Fire Ecology and Fire Management Congress.

10. 1 Hectare = 2.471 Acres.

has the highest number of homes in the UWI; based on the above definitions, there are almost 5.1 million homes in California's UWI. Based on U.S. Census 2000 data, this accounts for 41.75% of the housing units in California. [11]

The USDA Forest Service conducted their own analysis, basing their definitions of interface and intermix regions on the population density, instead of the housing density.[12] They defined the UWI as regions with 40-400 people per square mile, and derived their data from LandScan 2000, an international population data set prepared by Oak Ridge National Laboratory for the Department of Defense. LandScan is a 30-arc second grid coverage, with an estimated ambient population per pixel; it was determined that there were approximately 4 pixels per square mile. The population data was then separated into 48 layers to separate each of the states; the state-level population totals were then compared to the 2000 U.S. Census state population data as an independent check of reliability. Based on the USDA Forest Service's definition of the UWI, it was determined that there were 34,085,106 people living in the UWI of the 48 contiguous states; of those, 1,475,472 live in California's UWI. This accounts for 4.36% of California's total population.

Very clearly, these recent development patterns have led to new fire fighting challenges. The resulting fires are now specifically known as urban wildland interface [UWI] fires.

UWI fires are unique from a viewpoint of classical firefighting, planning and suppression techniques because fire suppression in such areas frequently involves the presence of large numbers of people and structures in areas that heretofore were subject only to wildland fire problems and suppression techniques.

11. U.S. Census 2000 data records 12,214,547 housing units and 33,871,648 people in California.

12. "Using GIS to identify potential wildland-urban interface areas based on population density"; Matt Kamp & Neil Sampson, USDA Forest Service, 4/14/2003. www.sampsongroup.com/papers/wui_paper.pdf.

2.1. The Urban Wildland Interface (UWI).

The urban wildland interface can be defined as an area where urban structures (both residential and commercial) are located adjacent to or interspersed within a wildland area. While the UWI is not a fire hazard in itself, climate and topographic conditions (namely: heat, low-humidity, high winds, and steep terrain) can create an area which is a dangerous fire waiting to happen. In recent decades, it has become increasingly apparent that the composite created by the UWI poses a fire risk unlike either urban areas or wildland areas alone. This report discusses lessons learned about fire risk at the UWI, and proposed building standards designed to better protect structures located within the UWI.

In the 1950s and 1960s the UWI fire problem seemed primarily restricted to Southern California. However, patterns of development and fires associated with UWI issues have now manifested themselves in Northern California (notably in the Berkeley Hills fire of 1980 and the Oakland Hills fire of 1991), as well as in such diverse states as Colorado, New York, Georgia and Florida. In 2004, projections for major UWI problems show extremely high levels of UWI fire risk in the states of Arizona and New Mexico. Based on these observations, UWI-related fires in California are clearly part of a statewide problem with issues that are national in scope.

While it may be fairly obvious that flammable wildland vegetation can endanger nearby humans and structures, the fire risk that humans pose to the wildland vegetation itself is perhaps less well-understood. Put simply, wildland vegetation can threaten humans and their structures, but humans and their structures can also threaten wildland vegetation in a fire-safety sense[13]. Upon further examination this makes sense— after all, it has long been known that metropolitan visitors to wildland areas are a significant source of forest fires[14].

This synergistic effect that takes place at the UWI hints at some of the difficulties associated with preventing UWI fires. A century ago the UWI fire threat was much less severe due both to fewer people living in wildland areas, and the fact that wildland vegetation was both healthier and less fire prone[15]

Paradoxically, the health and fire risk of our wildland vegetation has been adversely affected by our past successes in forest fire prevention. After devastating wildland fires in the early 1900s, the US Forest Service became extremely vigilant about not only preventing forest fires, but also about extinguishing such fires as soon as they began. As a result, American forests were not thinned by forest fires nearly as frequently, and they became more dense and overgrown than ever before, increasing the risk of fire[16]. As an indication of how common it has been historically for natural forest fires to occur, it is worth noting that in many parts of the world wildland fires are a natural part of the life cycle of wildland vegetation. For example, in parts of Australia, as well as in North America, there are plants whose seeds cannot grow without the heating and thinning effects of wild fire[17]. The current fire dangers presented by much of our wildland vegetation have

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13. Jaffe, Matthew. "Living With Wildfire," Sunset Magazine. April 2001. p.124-125.

14. For more on this topic, see Folkman, William S. "Urban Users of Wildland Areas as Forest Fire Risks," USDA Forest Service Pacific Southwest Forest and Range Experiment Station, Research Paper PSW-137. Berkeley, January, 1979.

15. Jaffe, Matthew. op. cit.

16. Jaffe, Matthew. op. cit.

come as a consequence of depriving our forests of decades of thinning provided by naturally occurring forest fires.

2.1.1.Wildland Fire Spread Patterns

A variety of spread patterns are reflected in reviews of UWI fires. These range from very dramatic flame fronts many feet wide and many feet high, threatening large groups of homes to less intense wind-driven fires, which will pass by residence structures relatively briefly, provided fuel density is low.

Figure 1: Illustration of a well-maintained interface between open space and housing in Los Alamos New Mexico which provided a benign route of passage for ground fire near homes with defensible space. (Photo courtesy of R. Crawford.)

The extremes of these fire conditions, crown fires and ground fires, can be found in reports for the Southern California fires of 2003. An additional factor contributing to the destructiveness of these fires, based on our analysis, was a phenomenon known as a brand fires. These factors, in conjunction with the topography itself, all contributed to the specific damage patterns observed.

One important characteristic of UWI fires is that such fires have essentially two means by which to spread: on the ground, using buildings and ground fuel to propagate themselves, or overhead, using treetops and pieces of burning debris (known as "brands") that have become airborne in the wind[18].

2.1.1.1. Ground Fires

Ground fires represent perhaps the most benign pattern of spread by wildland fires. Such fires tend to be driven at rates that are proportional to occurring winds if topographical and fuel densities are essentially constant. The hazard they pose to nearby structures is a function of wind velocity and, importantly, fuel density on the ground, provided a ground fire does not make the transition to the more intense crown fire. Ground fires are the most readily controlled type of UWI fire and provide the lowest degree of fire hazard in the absence of large amounts of fuel in the forms of brush and other undergrowth.

17.William, F.A. "Urban and Wildland Fire Phenomenology," Prog. Energy Combust. Sept 1982. Vol. 8, p. 352, and Attiwill, PM. "Ecological Disturbance and the Conservative Management of Eucalypt Forests in Australia." Forest Ecology and Management. 1994. 63(2-3): 301-46.

18. Wilson, Rexford. "Protecting Your City from Conflagration – By Design," National Fire Protection Association MP 65-1. p.3.

2.1.1.2. Brand Driven Fires

The term “brand driven” fires refers to so-called “spotting” – repetitive localized ignitions caused by burning materials in advance of movement of the main fire front. “Spotting” is the result of brands being blown ahead of the fire front, landing on combustible material, and igniting additional blazes in advance of the main fire front. Such brands commonly travel 1,000-3,000 ft in high winds, and in some cases have been known to travel well over a mile[19] with their numbers/density reflecting the size and types of fuels in the approaching fire. This type of fire spread is well-documented in wildland fires.

In the present case an important issue for UWI areas is the role fires caused by brands play in actively spreading fire to nearby buildings. Detailed studies of reports and photos from the Southern California wildfires of 2003, as well as fires in other areas such as the Florida fires of 2002, illustrate the importance of this mechanism of fire spread.

2.1.1.3. Crown Fires

Crown fires represent the most dramatic hazard. These are large well-developed fires, which sweep from tree to tree driven by dry winds and prevailing fuel loads. Well-developed crown fires pose the highest fire hazard and fire threat to structures in their path and to fire fighting personnel. The worst possible combination of conditions in a UWI fire is a well-developed crown fire, high prevailing winds, and a high density of structures such as occurred in the Oakland Hills fire in 1991.

When spotting occurs in a crown fire, the responding fire crews are taxed to their limit in several ways. One way is purely tactical in nature— once a fire has begun spotting, there is a lack of a definite fire front for firefighters to attack. This can lead to confusion and frustration among firefighters who must constantly adjust to the development of new fronts. Other problems are logistical—the distances involved in spotting are often so great that they force dilution of manpower and equipment. Furthermore, the speed at which brands travel is often much faster than the speed at which the fire crews can adequately respond[20].

2.1.1.4. Role of Topography

The role of topography is important in the majority of UWI fires in California. Conversely, examples of wildland fires where topography does not play a major role are available in fires both within and particularly outside of California. In California, topography remains a variable of primary importance, both as it impacts fire spread and accessibility for firefighting.
An example of the effects of topographic influences along with other factors affecting fire movement was provided during the Grand Prix and Old fires in San Bernardino

19. Wilson, Rexford. “The Los Angeles Conflagration of 1961- The Devil Wind and Wood Shingles,” NFPA Quarterly. Boston, January 1962. p. 275.

20. Wilson, Rexford. op cit. p. 280.

County, in the area south of Lake Arrowhead in the fall of 2003. In those cases, onshore Santa Anna winds blowing down slope initially pushed fire fronts to the south and west from the interior. Later, however, winds shifted to offshore and fire spread patterns reversed themselves. When that occurred, fire fronts moved up many of the same slopes the fires had traversed earlier but from the opposite direction, burning fuel that remained there after the initial exposure had taken place.

2.2. Damage Mitigation and UWI Fires

Study of past UWI incidents has provided information concerning UWI fire dynamics as well as guidance for potential mitigation approaches to reduce or eliminate UWI fire threats. For example, while we have learned that particular weather, vegetation, and topographic conditions can pose significant risks in terms of UWI occurrence, fire experience has also shown that certain landscaping and particular approaches to construction in UWI areas can not only protect individual structures against damage from fire, but can also help to contain the spread of the fire as well.

One fire that demonstrated the importance of home construction techniques and materials was the November 1961 Bel Air fire in Los Angeles, CA. Over two days, this conflagration destroyed or severely damaged over 513 homes and 24 other structures in Bel Air and Brentwood, making it North America's single worst conflagration in 38 years[21].

After the post-fire investigation was complete, it became clear that, in addition to the Santa Ana winds, wood-shingled roofs were the major cause of this blaze's destructive power. One danger of non fire-retardant wood roofing materials is obvious—burning brands are much more likely to ignite a spot fire if they find available fuel where they land and when such a brand lands on a wooden roof covering, it is very likely that that the wooden roof will ignite. Consistent with the preceding, of the 484 shake homes destroyed in the Bel Air fire, 98.4% first ignited on the roof, compared with only 16.5% of non-shake homes destroyed in the same fire[22].

Another, perhaps less obvious, danger of non fire-retardant wood roofing materials is their propensity to create brands themselves. Burning wood shingles and shakes can easily get picked up by high winds, and go on to start other spot fires. This phenomenon was directly observed by witnesses to the Bel Air fire, and was cited as a major cause of the Bel Air fire's rapid spread.

Since the Bel Air and other similar fire incidents, the dangers of wooden roofing have become common knowledge to the general public as well as the fire safety community. In California, there have been numerous UWI fires in which wooden shingles were cited as one of the main contributing factors, such as the Pebble Beach fire of 1987, and the Santa Barbara Paint fire of 1990.[23] As UWI fires have increased in frequency and destructiveness, fire

21. Wilson, Rexford. "The Los Angeles Conflagration of 1961- The Devil Wind and Wood Shingles," NFPA Quarterly. Boston, January 1962. p. 242.

22. Wilson, Rexford. "The Los Angeles Conflagration of 1961- The Devil Wind and Wood Shingles," NFPA Quarterly. Boston, January 1962. p. 271.

23. Graham, Hugh W. (Investigator). "Urban Wildlands Fire – Pebble Beach California, May 31, 1987," USFA Fire Investigation Technical Report Series. p.14 and Martin, Robert E, et. al. "Analysis of Structure Loss on Urban-

safety professionals have begun to accumulate theories and data confirming that numerous other construction features of homes – in addition to the performance of wood roofing materials - can play an important role in either exacerbating or mitigating the damage of UWI fires.

For example, prior to the fall 2003 fires, a significant fire which brought the roles of various construction methods, details and materials to light, was the Oakland Hills fire of 1991. By way of background, in terms of area, the Oakland Hills fire was not very large, about 2.5 square miles, but in terms of damage it was the worst UWI fire in California history to that point. It resulted in 25 deaths and 150 injuries, as well as the destruction of over 3,000 buildings including 2,449 single-family homes and led to an estimated $1.5 billion in damage[24].

As was the case in the Bel Air fire, non fire retardant wood roofing materials and assemblies, high winds, and steep terrain were all cited as major contributors to the destruction in the Oakland Hills fire. However, studies of the surviving homes revealed construction methods and materials that aided in the defense of many homes. These included the roles played by noncombustible or ignition resistant exterior wall surfaces, double-paned windows, roof projection configurations and of course - clearances to and nature of surrounding vegetation.

In the aftermath of the Oakland Hills fire, the benefits of noncombustible external walls (such as stucco) became apparent as did the role of combustible wall coverings that resisted ignition from small brands. Thus, while going into that incident, it was commonly accepted that a roof is the most vulnerable part of a building in a wild fire; it was becoming more and more apparent that vertical surfaces of a building could also ignite – but to varying degrees - when exposed to brands, radiant heat from nearby structure and/or burning brush. Given these facts, it is not surprising to note that, in the Oakland hills fire, most – but not all - of the surviving homes on the fire perimeter had stucco-clad exterior walls, as did surviving homes within the burned-out area[25].

In addition to the nature of exterior wall surfaces, double-paned windows – required by the California Energy Code were also noted to have a mitigating factor on fire spread to building interiors during in the Oakland Hills fire. Like exterior walls, windows are often exposed to radiant heat in a UWI fire from nearby brush and buildings. Unlike walls however, windows (especially large windows) can shatter when exposed to radiant heat, creating an opening that will allow fire to easily ignite inside that same building. Conversely, multiple glazed or safety glazed windows are more resistant to thermal breakage, and in the Oakland Hills fire they helped protect homes, even in areas of maximum fire intensity[26].

Another feature common to many homes that survived the Oakland Hills fire were the presence of roof projections ranging from large overhanging gables to short, box-like eaves. The former will pose a hazard to a structure during a fire incident in that they trap heat and

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Wildland Interface Fires," Research Proposal to the California Department of Forestry and Fire Protection. September 1990. p.5.

24. The Oakland/Berkeley Hills Fire. NFPA report sponsored by the National Wildland/Urban Interface Fire Protection Initiative. p.3.

25. Kluver, Mark. "Observations from the Oakland Hills Fire," Building Standards. March-April, 1992. p.6.

26. The Oakland/Berkeley Hills Fire. NFPA report sponsored by the National Wildland/Urban Interface Fire Protection Initiative. p.9.

flames radiating from an adjacent fire or a fire growing from below as from burning shrubs. Moreover, the undersides of such eaves can easily become ignited in most cases and they may also often contain attic vents which readily allow flames to penetrate the interior of a structure. In the Oakland Hills fire, virtually all buildings that survived the fire had minimal or no roof projections, whether they were located on the fire perimeter or on the interior of the blaze. Other types of building projections and appurtenant structures — such as wooden decks and patios—also contributed to the loss of many homes, though there were also structures that survived despite containing such projecting elements[27].

Finally, the Oakland Hills fire further demonstrated the importance of having adequate clearance between structures and combustible vegetation. While landscaping is often an afterthought when it comes to fire protection, one can prevent fire spread both to and from a structure by reducing the amount of combustible vegetation and other fuel around it. In the Oakland Hills fire, there were many examples of homes that were saved due to well-maintained clearances, even when they were located across the street from homes that were completely destroyed[28]. For any structure located at the UWI, the yard can and should be an integral part of its fire protection.

As a result of studying the Oakland Hills fire and the other conflagrations described above amongst others, our understanding of damage mitigation techniques in UWI fires has greatly improved. Due to the relatively contemporary nature of the UWI fire problem, however, we continue to learn more about damage mitigation with each successive UWI fire.

For example, in 1993, massive wild fires in Southern California reinforced the importance of the above construction methods and materials, and shed light on at least one other method for damage mitigation. As part of those events, for eight days in November of 1993, 22 UWI fires burned throughout Southern California, from Ventura County all the way to the Mexican border. These combined fires destroyed over 1,000 buildings, claimed four lives, and caused almost $1 billion in damages[29].

In the aftermath of those 1993 fires, many of the construction features that saved homes in the Oakland Hills fire were identified as having also saved homes across Southern California from devastation. One home in Laguna Beach, for example, survived despite being located in a 2-3 block area in which *every other home* was completely destroyed. Although firefighters were unable to reach the home until two hours after the fire front passed through the neighborhood, the home endured because it contained a combination of the features discussed above: noncombustible roofing, noncombustible exterior walls, small double-paned windows, and minimal roof projections that contained no vents underneath. Such "miracle houses" are known from other factors and can provide insight into combinations of features providing maximum freedom from fire hazard.

The Southern California fires of 1993 further reinforced the importance of a construction feature related to building projections that can also help mitigate UWI fire damage: protected eaves. As detailed above, eaves and other roof projections are dangerous because the

27. Kluver, Mark. "Observations from the Oakland Hills Fire," Building Standards. March-April, 1992. p.7.

28. The Oakland/Berkeley Hills Fire. NFPA report sponsored by the National Wildland/Urban Interface Fire Protection Initiative. p.8.

29. Kluver, Mark. "Observations from the Southern California Wildland Fires," Building Standards. January-February, 1994. p. 12.

undersides of the eaves can trap flames and radiant heat and become easily ignited. Furthermore, eaves often contain eave vents that will allow trapped heat and flames to enter the structure. Some eaves, conversely, were noted to *protect against such risks* because they not only lacked eave vents, but they also included protection for combustible eave elements (usually in the form of stucco) underneath, guarding combustible roof beams against ignition. Several homes that contained sizable roof projections were able to survive severe exposure from the Southern California fires of 1993 precisely because their roof projections were protected and contained no roof vents[30].

While new construction techniques and materials that protect against fire dangers are constantly being discovered, it is ultimately a combination of these factors that will best protect an area against the threat of UWI fires.

While, UWI fires have been known to occur in flat areas (such as the Florida Palm Coast fire in 1985), and areas where wooden roofing was largely absent (as in the Los Alamos, NM during the Cerro Grande Fire in 2000), and other anomalous locations, and this tells us that a broad range of factors as noted in the preceding – i.e. topography, vegetation AND construction materials and designs - must be considered when evaluating the susceptibility of a certain area to a catastrophic UWI fire[31].

Nevertheless, the data has clearly shown that certain aspects of UWI building technology can affect the chances of an UWI community surviving a fire. The data also demonstrates – as is detailed in this report – that with continued research and aggressive use of proven mitigation techniques - the hazards from such fires can be significantly reduced.

2.3. Fire Risk and Fire Hazard at the UWI

The terms risk assessment and hazard assessment are often used to analyze complex problems even though, the base terms - *risk* and *hazard* - are frequently used without an appropriate context being set for their use. As such, for this report **fire risk** is defined as the likelihood of a fire incident occurring under a specified or stipulated set of conditions. **Fire hazard** is defined as the potential consequences of a fire occurring under a defined set of circumstances. Thus, there will be multiple fire hazards/outcomes relating to a single, defined fire risk.

The building code and fire safety communities are increasingly applying the concepts of fire risk and fire hazard in conducting fire safety analyses [sometimes referred to as fire hazard analysis] to address the problems posed by new developments and/or performance-based design approaches. [32, 33]

30. Kluver, Mark. "Observations from the Southern California Wildland Fires," Building Standards. January-February, 1994. p. 15.

31. Abt, Robert, et. al. "The Florida Palm Coast Fire: An Analysis of Fire Incidence and Residence Characteristics," Fire Technology. August 1987 Vol.23, No. 3, p.230 and Cohen, Jack D. "Examination of the Home Destruction in Los Alamos Associated with the Cerro Grande Fire- July 10, 2000," USDA Forest Service, Rocky Mountain Research Station. Report from the Fire Sciences Laboratory, Missoula, Montana. p.4.

32. See for example: The SFPE Guide to Performance-Based Fire Protection-Analysis and Design of Buildings, 2000. Society of Fire Protection Engineers and National Fire Protection Association, Quincy, MA. Prepared by The SFPE Task Group on Performance-Based Analysis and Design, Eric R. Rosenbaum, P.E., Chairman, 2000.

33. Utilization of these approaches are risk-based and first require delineation of the level of fire risk for the problem being addressed. For example, if one is analyzing a situation with no known history of fire occurrence, the resulting

Historically, high levels of fire risk are known to exist in UWI situations. These levels of risk are intrinsic and will continue to exist in forested areas where development takes place. Given the knowledge that fire risk at the UWI is quite high, resultant hazards must be addressed comprehensively. Thus, one reasonable objective for an analysis of UWI based fire and construction issues would be "to assure the safety of inhabitants and preservation of a particular community of homes subjected to ground fires." Similar analyses could be conducted for crown fires. Such analyses will lead to the determination of factors and features that affect acceptable outcomes of such fires and should address both life safety and property safety issues.

The formal methodology that may be followed to accomplish such analyses includes the following steps as adapted from the reference in footnote 31:

1. Define problem scope.
2. Identify fire safety [design] goals.
3. Define stakeholder and design objectives.
4. Develop performance criteria.
5. Develop design fire scenarios.
6. Evaluate the system design performance as they address [or do not successfully address] stakeholder and design objectives.
7. Where problem solution proposed does not meet stated objectives, develop mitigation strategy to meet the design objectives, or modify the design objectives as appropriate.

2.4 Modes of Building Failure at the UWI.

To the casual observer, there seems to be no rhyme or reason as to why wildland fires sweep through a neighborhood and destroy many homes but leave others intact. The purpose of this report is, in part, to formally address this often destructive process and determine what we can conclude with scientific certainty about the failure modes and processes operating when such events occur.

In addition to the fire hazard analysis techniques described above, Failure Modes and Effect Analysis [FMEA] provides a ready framework to analyze these events and determine possible failure modes so that mitigation can be applied to reduce the likelihood of a catastrophic failure occurring. For a full treatment of FMEA techniques a range of references exist and can be found at www.fmeainfocenter.com.

If it has been determined that a reasonable risk exists that an UWI incident will affect a given home or group of homes – all possible hazards must be understood and mitigation must be applied to the hazards deemed significant. This must be done in cost effective ways.

Using FMEA, we can, for a hypothetical building, consider the hazards such a building faces. Overall, there appear to be at least three major pathways for such a building to be destroyed.

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risk level will be low. In that sort of situation, then, the critical issue would be to determine threshold values beyond which identified fire hazards – resulting from the degree of risk - might exist.

1) A building may ignite on the outside and burn essentially from the outside in.
2) A building may ignite on the inside from an exterior source– but not on the outside.
3) A building may ignite on the outside and fire spread to the inside through eave vents to an attic or by glazing being compromised and an interior fire developing.

FMEA may be used to address such pathways described above. By breaking down and detailing possible pathways to building destruction possible failure modes, possible mitigation strategies can be understood. The figure below shows in simplified from how such processes operate schematically. One can see how such FMEA methods can be used for individual homes or even to address fire behavior in neighborhoods as well.

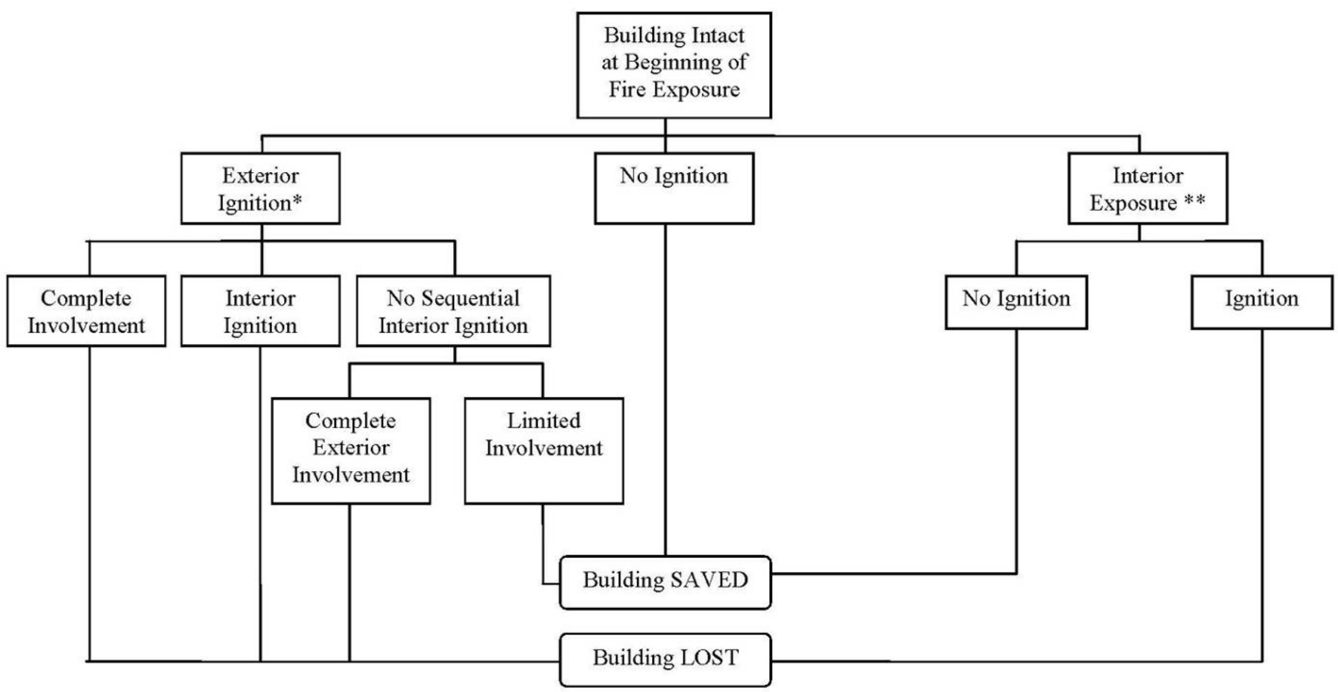

Figure 2: Residential Building Failure Modes.
*e.g. siding roof assembly, foundation ignition
As by brand exposure or radiation exposure through vents or following window breakage.**

3. The Fires of Fall 2003 in Southern California

3.1. Timeline

The fires of fall 2003 in Southern California amounted to the worst fire season and largest application of firefighting resources in California's history and are well summarized in the Governor's Blue Ribbon Commission report.[34] Due to the heretofore-unique combination of fires that occurred, we've summarized a portion of the chronology from that report in the text which follows to give a reader a sense of what some have described as the …fire siege of 2003:

> "The fires began on Tuesday, October 21, 2003. The initial fire was the Roblar 2 fire, which began near Camp Pendleton around 12 noon. Shortly thereafter, at approximately 2 p.m, the Grand Prix fire began near Rancho Cucamonga, and at 4 p.m. the Pass fire began in Riverside County……
>
> Two days later, on Thursday, October 23 the Piru fire began near Ojai and, the first major fire in Northern California, the Palermo fire began in Butte County…….
>
> The following day, Friday, October 24, 2004 the Olinda fire began in Shasta County and Verdale fire developed in Los Angeles County. Later in that day, the Rancho 8 fire began in Tehema County and the Happy fire began in Santa Barbara. On Saturday, October 25, 2003, the Old fire began midday at the Northern edge of San Bernardino County and the Simi fire began in the early afternoon near the city of Moorpark. Later in the day the Cedar fire began in the Cleveland National Forest in San Diego County. In all these cases, winds, high temperatures, and dry forest conditions played a significant role…
>
> On Sunday, October 26, 2003 the Otay/Mine fire began early in the morning and the Paradise fire in San Diego County began midday. The chronology for additional fires and suppression of all fires continues through Tuesday, November 4..."

3.2. Fire Areas

For purposes of this study, the focus has been on the effects of six fires in Southern California, which burned a total of 658,822 acres and accounted for the destruction or damaged of an estimated 3,764 residences in locations shown in Figure 2. These fires accounted for, by far, the majority of damage done to buildings in all the Southern California UWI fires of 2003.

Following the fires, damage assessment teams from both the Office of the State Fire Marshal and local agencies conducted extensive evaluations to assess the impact of construction features critical to the fire performance of buildings that were destroyed. As part of these activities, data was also collected for similar buildings and building constructions at different sites which were identified as having been both damaged and undamaged in the same fires. These data sets which included comparative features, have provided the bulk of the information used in this study. Data format and collection issues will be discussed in depth

34. See Blue Ribbon Report, page 27.

later in this report when statistical interpretations are made of data provided to the Fire Cause Analysis project team.

The reader should also note that, although there were occasional multiple family dwellings and commercial buildings located in the fire areas, the vast majority of lost structures were single-family dwellings. For that reason, the focus of this analysis has been building construction techniques used on fire-affected single-family dwellings.

The area of Southern California in which the fires in this report took place are shown in the following map:

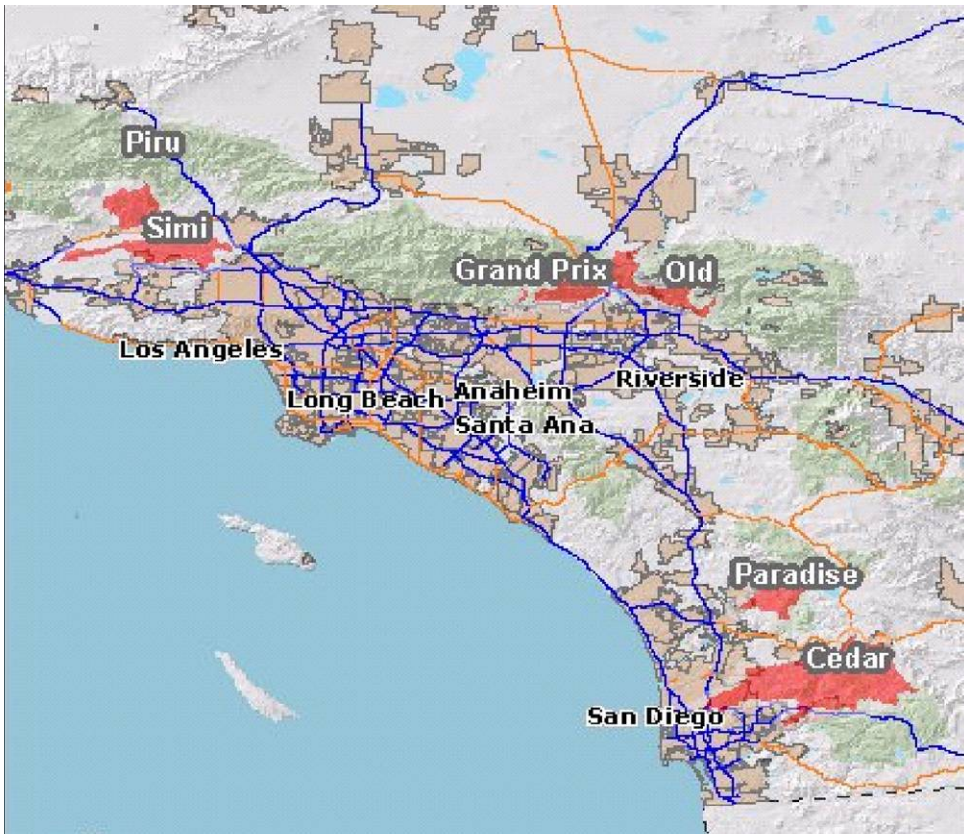

Figure 3: Map showing locating of the six major 2003 UWI fires in S. California.

A summary of the numbers of acres and structures involved in each of the fires studied follows:

	Cedar Fire	Simi Fire	Old Fire	Piru Fire	Grand Prix Fire	Paradise Fire
Acres Burned	280,278	108,204	91,281	63,911	58,448	56,700
Structures Destroyed	2,820	315	1,003	1	196	415
Structures Damaged	63	11	N/A	N/A	82	15

Residences Destroyed	2,232	37	993	1	135	221
Residences Damaged	53	11	N/A	N/A	71	10
Structures in Survey Destroyed	398	9	24	0	190	11
Structures in Survey Damaged	75	11	6	0	80	16
Residences in Survey Destroyed	131	7	12	0	136	71
Residences in Survey Damaged	70	9	1	0	80	13
Cost of Fire Suppression	$32.5 million	$10 million	$42.3 million	N/A	$11.6 million	$12.6 million
*** Rows 2-5 reflect overall incident numbers. Rows 6-9 reflect number of buildings in survey data.**						

Table 1: Number of Acres and Structures involved in 2003 S. California fires.

Locations of the specific fire incidents are shown in the following figures:

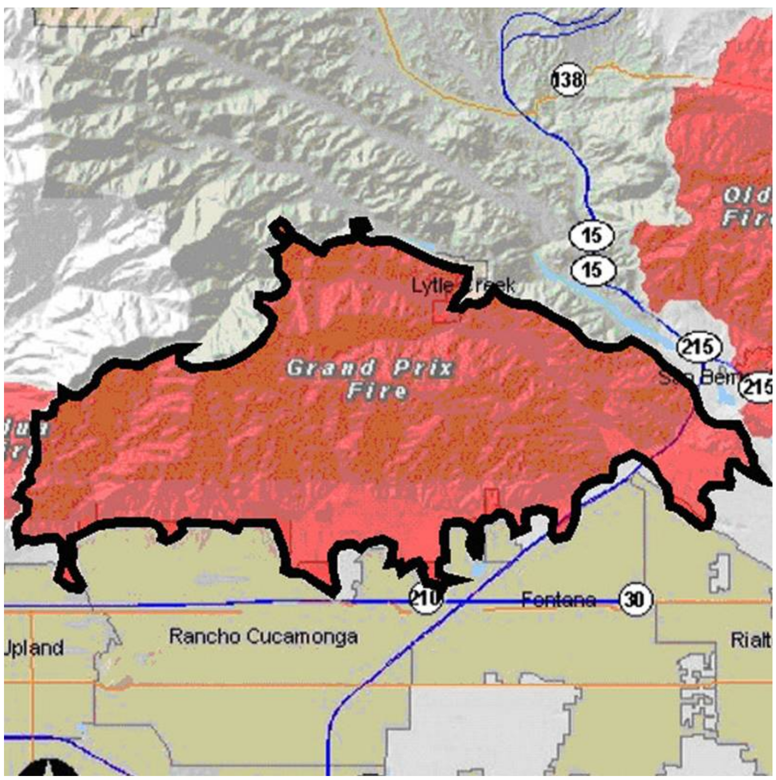

Figure 4: Map showing location of Grand Prix fire.

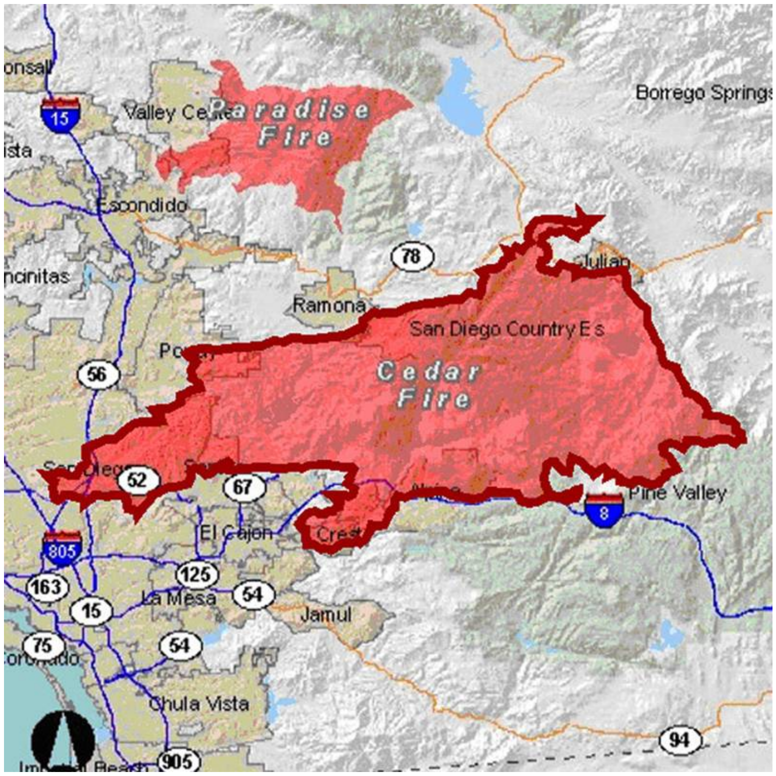

Figure 5: Map showing location of Cedar fire.

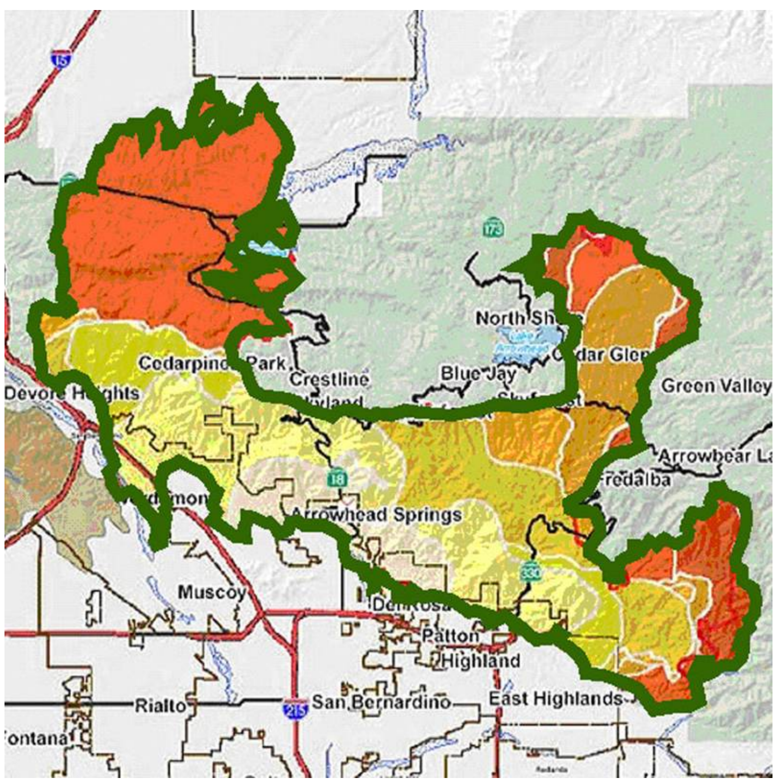

Figure 6: Map showing location of Old fire.

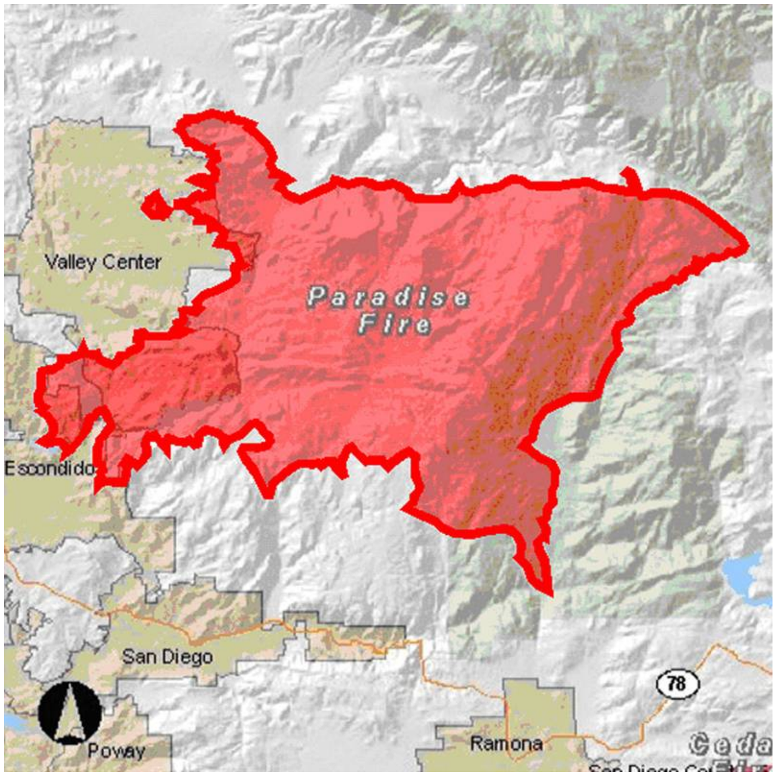

Figure 7: Map showing location of Paradise fire.

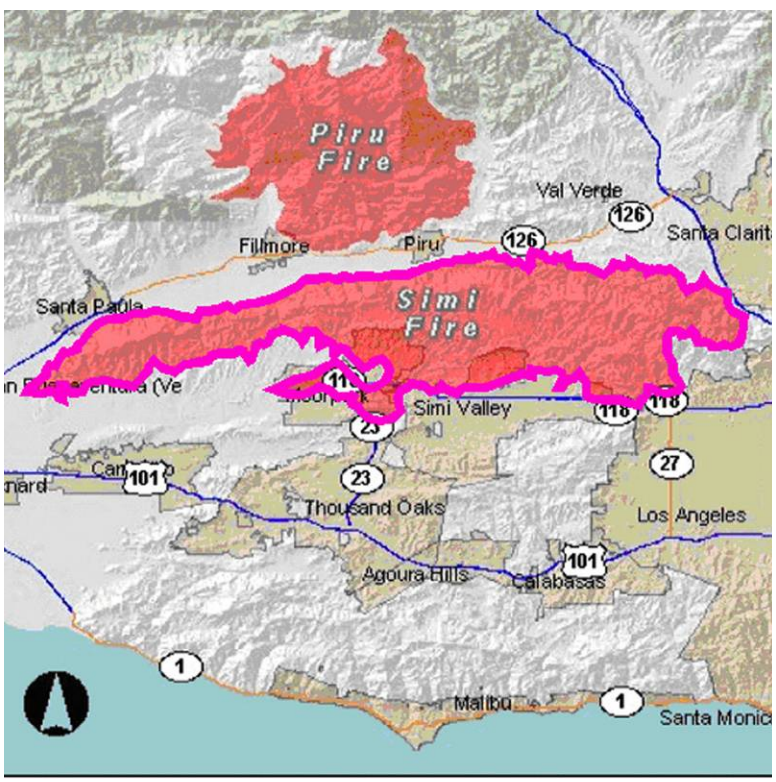

Figure 8: Map showing location of Piru and Simi fires.

3.3. The Data Set

Large acreages were involved in each of these fires and most involved large numbers of buildings. As such, the data gathered represents a fairly large sample and cross-section of buildings destroyed, damaged and left undamaged. This data set, while large, is somewhat random within each fire's boundaries because of the vagaries and shear mass of the possible number of sites to sample. Thus, each fire studied contains different sized samples of its total building population.

There is no complete data for the over 3,600 residences destroyed and countless others damaged in these fires. Consistent with the preceding, the data available frequently included groups of homes from the same communities, while other communities within a given set of fire boundaries may not have been sampled.

Figure 9: Wind-driven fire in urban setting. Delmar in the fall 2003 fire. [Photo courtesy of R. Crawford.]

Samples of homes within the same communities were useful since many of these had similar construction characteristics, meaning that a particular segment for example showed an abundance of stucco walls and/or tile roofs all of which were constructed around the same time.

Also while evaluating available data, we noted that definitions such as "destroyed" versus "damaged" may have been applied differently by the assessment crews.

The reader is encouraged to consider the wide variations in numbers of residences involved in each of the fires and also how those numbers reflect development density for a given fire or area within a fire at the time of these incidents.

For example, one might compare and/or contrast the urban conflagration which occurred in Delmar with the lack of damage at the East Highlands Ranch project. Similarly one can compare the fires in San Diego County or the varied performance of the developments in the recently built Rim of the World area with the decades old cabins lost in the fires above San Bernardino.

Likewise the types of vegetation and the ecological issues involved are important; of note is the fact that the Piru fire involved few homes since it occurred in an area that is primarily set aside as habitat for the California condor. Also of interest is the role that MAST [the Mountain Area Safety Task Force] played in the fires in the San Bernardino Mountains. Those fires involved pine ecology heavily affected by drought and forest management issues often common to UWI areas. Conversely, the fires east of San Diego involved primarily chemise ecology. Such differences are part of the profiles that are important in evaluating UWI fire incidents

Figure 10:Overview of all fire GPS points. Purple=Paradise, Blue=Cedar, Red=Grand Prix, Green=Old, Yellow=Simi.

A review of the specific fires included in the study follows:

Cedar Fire

The Cedar Fire began on the fourth day of the 2003 Fire Siege and accounted for the largest number of destroyed residences of any of the UWI fires studied. Rough terrain, difficult access, an abundance of natural vegetation, and high winds impeded the initial assault on the fire. This fire destroyed almost three times the acreage of the second largest fire, the Simi Fire, and more than twice the number of residences which were destroyed in the Old Fire. The cost of suppression for the Cedar Fire was $32.5 million (CalMAST).

Overall, 2,820 structures were destroyed and 63 were damaged by the Cedar Fire, giving a ratio of structures destroyed to those damaged of approximately 45:1. The information available for this analysis, 398 homes destroyed to 75 homes damaged, results in a ratio of 5:1. The difference between these ratios may simply be related to the area in which the sampling was performed. An interesting variation in the data shows that the number of residences considered to be damaged by this survey team was higher than those determined by the CDF Incident Report and the San Bernardino Joint Information Center (SBJIC). The CDF survey data indicates 14% of all structures damaged or destroyed in this incident were included in this survey.

Figure 11: Close-up of Cedar fire GPS points.

Simi Fire

The Simi Fire began a few hours before the Cedar Fire near the city of Moorpark, yet in terms of homes destroyed it was not nearly as destructive as the Cedar fire. The Simi fire affected fewer homes than the Cedar Fire, despite a total burn area more than one-third larger. The cost of fire suppression for this fire was $10 million (CDF). The ratio of homes destroyed to those damaged in the figures presented by the San Bernardino Joint Information Center was 3:1; in the information collected by the CDF, the ratio was closer to 1:1. This may be due to the extremely small sample size, as only 16 residences were included in this survey. The CDF survey data included 33% of all residences damaged or destroyed in this incident.

Figure 12: Close-up of Simi and Piru fire GPS points.

Old Fire

The Old Fire began five hours before the Simi Fire at the northern edge of San Bernardino County. The area burned included parts of the San Bernardino National Forest. 993 residences were destroyed and over 91,000 acres burned. This is over 26 times the number of residences and 84% of the acreage destroyed in the Simi Fire. The cost of suppression for the Old fire was $42.3 million (CalMAST). Detailed survey data on this incident was extremely limited, despite the large number of homes destroyed and an unknown number of homes damaged. Data on only 13 properties accounting for 30 structures total were included in the survey information available.

Figure 13: Close-up of Old fire GPS points.

Piru Fire

The Piru Fire was one of the first fires in California, beginning on October 23, 2003 in Ventura County near Ojai. The acreage burned was located mainly within largely uninhabited areas of the Los Padres National Forest, which may help to explain the small number of structures destroyed relative to the other fires. No data was collected for any structure destroyed in this fire, but it is known that very few were destroyed or damaged.

Grand Prix Fire

The Grand Prix Fire began on October 21, 2003 near Rancho Cucamonga. This fire destroyed 54,448 acres and 135 residences, in addition to damaging 71 other residences. This fire also extended into the San Bernardino National Forest which accounts for the low number of residences lost per acre. The cost of suppression for this fire was $11.6 million (CalMAST). Data collected for each residence surveyed in this fire varies somewhat in format and information quality.

The information from the San Bernardino Joint Information Center accounts for 278 structures damaged or destroyed, and the CDF survey accounts for 270 structures damaged or destroyed. This suggests that a high percentage, over 98%, of the population affected by this fire was surveyed. The ratio of structures destroyed to those damaged was in the range of 2:1 for both agencies conducting surveys.

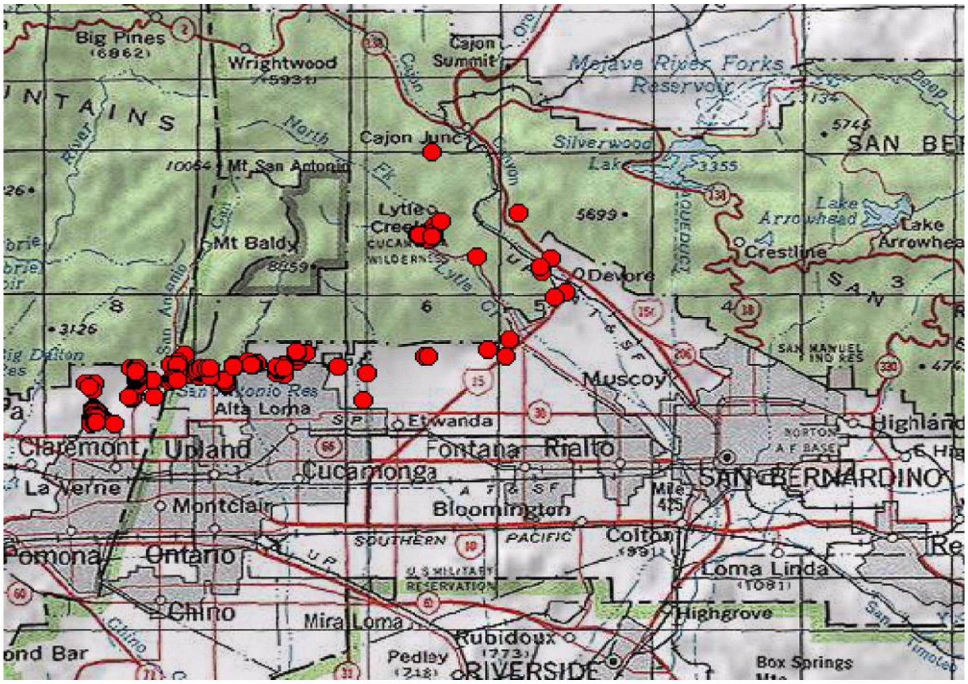

Figure 14: Close-up of Grand Prix fire GPS points.

The California Department of Forestry conducted a study to determine the value of structures saved by fire suppression action in the Grand Prix Fire. This study only included main structures (not outbuildings or vehicles) and did not take into account the contents of the home, but rather the base value of the home, given its construction type, size and location.

The values of the homes ranged from a low of $75,000 per residence in the Happy Jack area of San Bernardino County to a high of $1,000,000 per residence in the Archibald, Euclid Crescent, and Alpine areas of San Bernardino County. A total of 1,038 residences in San Bernardino and Los Angeles Counties were saved due to the Grand Prix Fire suppression efforts, accounting for $300,520,000 in property value. The greatest number of homes saved in any particular area was 250 homes in the Happy Jack area, followed by 62 homes saved on Padua Avenue. These two areas alone accounted for just under $55 million in preserved property value.

Paradise Fire

The Paradise Fire began on October 26 of 2003 in Valley Center in San Diego County. 56,700 acres were burned, and 231 residences were either destroyed or damaged. The cost of suppression for the Paradise fire was $12.6 million (CDF). The ratio of homes destroyed to those damaged was higher in this fire than in the Grand Prix fire. Based on the information gathered by San Diego County this ratio was about 22:1, based on CDF survey data, this ratio is approx 6:1, much lower than suggested by the population. About 36% of the residences exposed to fire conditions in this incident were surveyed.

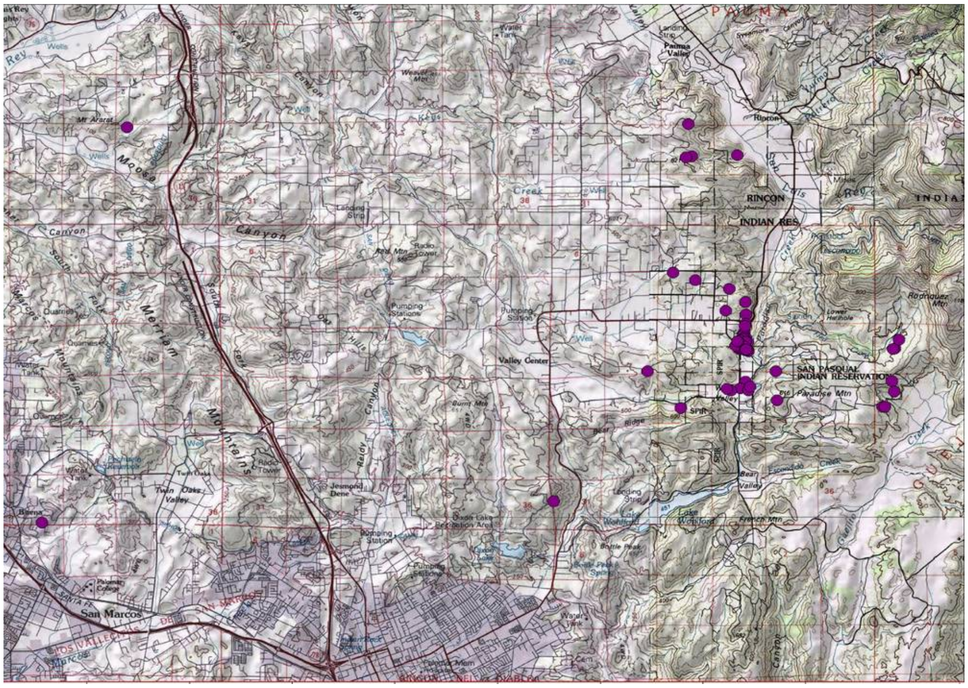

Figure 15: Close-up of Paradise fire GPS points

4. Design Features and Development Issues Affecting Building Fire Performance.

The development of homes and groups of homes in very high fire hazard severity zones and UWI communities [as well as other similar areas whose features encompass significant fire risk] are mandated to be accomplished as designated in California Health and Safety Code Section 13108.5.

Given the high level of probability that such homes will be exposed to fire conditions sometime during their useful lives, logic as well as studies accomplished to date show that attention needs to be paid to housing unit layout and site selection, as well as construction materials if such homes are to survive UWI fires.

Figure 16: Cul de sac location in greater San Diego following 2003 fire. Note continuity and essentially unburned condition of green belt surrounding burned homes demonstrating house to house spread independent of landscape conditions. Photo US News and World Report.

4.1. Development Profiles and Patterns.

In the context of this study, development patterns and profiles refer to the arrangement of buildings and overall level of building quality within a UWI development site. A development profile incorporates architectural choices made in terms of materials and styles, as well as density and arrangement within a given project. An example of such choices and characteristics involve separations between homes, which depending on treatment of that separation can provide either adequate or inadequate clearance during a wildland fire event.

Likewise, treatment of the actual interface between undeveloped spaces surrounding a development project and the initial ring of homes is an important aspect in planning. UWI issues will be most important at the margin of any project where an oncoming fire may encroach, especially if it is developed as a high density community in an area with limited fire fighting resources.

Thus, both development patterns and ecology - as reflected in the characteristics of the surrounding wildland - play roles in defining specific fire hazards which exist for a given project

Figure 17: Illustration shows fire characteristics associated with high-fuel density surrounding homes in one UWI area. Photo courtesy of R. Crawford.

4.2. Construction at the UWI Interface

Construction undertaken within UWI areas are, subject to treatment under a variety of regulatory processes in California. The primary means of regulating the nature of construction taking place in such areas is through Codes and Standards promulgated primarily at state level and secondarily through adoption of specific local ordinances.

Figure18: Wood shingle roofs burning on homes in partially completed development in Okanogan, Canada. Note absence of vegetation and available defensible space. Photo courtesy of Jack Cohen.

4.2.1. Codes and Standards

The **California Building Code**, the current version of which is the 2001 edition, governs virtually all buildings within the State of California. This code, adopted from the (model) 1997 **Uniform Building Code** and amended by the various state agencies contains provisions governing construction of residences in most areas of the State.

Specific areas deemed "very high fire hazard severity zones" in areas of state responsibility and other areas designated by a local fire agency however may be subject to additional regulations. The California Department of Forestry publishes a list of communities at risk, broken down by county. UWI communities may be designated as "moderate", "high", or "very high" risk by a local agency and, consistent with these designations, housing constructed there, given the higher than usual level of fire risk, should be designed and built to address the foreseeable hazards present.

Until recently, little, if any, comprehensive guidance as to how to best construct homes and projects in UWI areas **-** beyond the relatively brief treatment in **California Fire Code** Appendix IIA **-** has been available. Exceptions to this have been local efforts in several of the Southern California Counties and occasional municipalities. One example of such documents is the "Consolidated Fire Code" prepared by the County of San Diego with an effective date of November 16, 2001.

*In 2003 the **International Urban Wildland Interface Code** was published for the first time. This documents draws from previous versions of an Urban Wildland Interface Code, first published in 1995 by IFCI. While the newer document provides significant information and guidance as of the time of its preparation, the necessary underlying research to provide specific pass/fail fire performance criteria for key groups of* *assemblies found in that code was not available at the time of its initial publication. Likewise, analysis of data describing the response to fire conditions of the thousands of homes involved in the 2003 fires in Southern California was not available.*

For those two reasons amongst others, this report focuses on research describing fire performance attributes of key assemblies in such homes as well as descriptions of the fire performance of such assemblies in the 2003 fires. In this way, more detailed treatments of necessary pass/fail and related performance based criteria are being made available for the first time than were available when the initial ULI codes were promulgated.

In summary, there are currently four codes/standards applicable to the Urban Wildland Interface fire hazard. These are Public Resources Code Section 4291, the 2001 **California Fire Code** (which amends the 1997 **Uniform Fire Code**), National Fire Protection Association Standard 1144-Protection of Life and Property from Wildfire, and the **International Urban Wildland Interface Code.** The 2001 **California Building Code** does *not* specifically address this hazard currently.

4.2.1.1. Public Resources Code

Section 4291 of the Public Resources Code (PRC) applies to "State Responsibility Areas" (SRA). SRA is defined as (PRC Section 4126):

> a) Lands covered wholly or in part by forests or by trees producing or capable of producing forest products.
>
> b) Lands covered wholly or in part by timber, brush undergrowth, or grass, whether of commercial value or not, which protect the soil from excessive erosion, retard runoff of water or accelerate water percolation, if such lands are sources of water which is available for irrigation or for domestic or industrial use.
>
> c) Lands in areas which are principally used or useful for range or forage purposes, which are contiguous to the lands described in (a) and (b).

Thus, "SRA" invoices lands that are not owned by the federal government, and are unincorporated areas.

Paraphrasing, Section 4291 states that "…any person that owns, leases, controls, operates or maintains any building or structure *in, upon, or adjoining any mountainous area or forest covered lands, brush covered lands, or grass covered lands, or any land which is covered with flammable material* (italics added), shall at all times do the following:"

> a) Maintain a firebreak by clearing combustible and flammable vegetation a distance of 30 feet or to the property line around structures.
>
> b) Extend the firebreak up to 100 feet around structures if it is determined by the Authority Having Jurisdiction (AHJ) that a 30-foot firebreak is inadequate due to the extra hazardous conditions that may be present.

c) Maintain tree limbs such that they are greater than 10 feet from the outlet of any chimney.

d) Maintain any tree adjacent to a structure such that no dead limbs are overhanging the structure.

e) Maintain the roof of any structure such that it is free of leaves, needles or other dead vegetation.

f) Provide and maintain a screen (spark arrestor) over chimney outlets.

This section contains no provisions to assess the fire or ignition resistance of construction and/or building elements to be used in such areas. *Such guidance, however, is provided by the proposed SFM Standards.* Other provisions of this section will allow an AHJ to decrease the amount of defensible space required if the exterior of the structure is constructed of materials which are not easily ignited.

4.2.1.2. 2001 California Fire Code

The 2001 **California Fire Code** (CFC) amends the 1997 **Uniform Fire Code.** The specific sections relating to the UWI fire challenge are contained in Article 86, and Appendix II-A. However, this appendix has not been adopted by the State of California.

Article 86 requires a "Fire Protection Plan" be written for all new development within the declared UWI areas, consistent with the Interface Code. However, there are no specific requirements on the contents of the plan.

Appendix II-A's requirements are very similar to the requirements of PRC Section 4291, the difference being that Section 16 of Appendix II-A states in part that in addition to the portion of PRC 4291 that states who is responsible for maintaining the required fire safety measures, Section 16 adds that persons owning, leasing or controlling land *adjacent* to such buildings or structures are also responsible for maintaining such firebreaks. In other words, in contrast to Section 4291, Appendix II-A ignores the property line.

However, not having been adopted by the State thru Building Standards Commission procedures, Appendix II-A, must be specifically adopted in the local jurisdiction's code adoption ordinance to be enforceable after substantiated "Findings of Fact" have been determined and filed with the State.

4.2.1.3. International Urban-Wildland Interface Code

The **International Urban-Wildland Interface Code** (UWIC) is, as stated in its preface, designed to bridge the gap between enforcement of the **International Building Code**, and the **International Fire Code**. It has both building standards as found in the model building codes, and defensible space, access, and water supply requirements found in the fire codes.

In general, the UWIC would be applicable to only those parcels/areas deemed to be in a very high fire hazard area, or such areas designated by the AHJ. Once a building or sub-division site is found to be in an area where the UWIC applies, the site must conform to access and water supply requirements. Then, the site is evaluated based on critical fire weather frequency, slope and aspect of the site and the prevailing fuel model to determine the required ignition resistance of the structure(s) to be built there.

As with UFC Appendix II-A, it must be specifically adopted by the local jurisdiction to be enforceable after substantiated "Findings of Fact" have been determined and filed with the State.

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4.2.1.4. NFPA 1144-Standard for Protection of Life and Property from Wildfire

NFPA 1144 is similar to the UWIC in that it uses a rating system to determine the fire hazard severity for a given site, as well as similar requirements for water supply and fire department access. However, being a standard rather than model code, its requirements are much more general, leaving many specifics up to the AHJ.

NFPA 1144 also contains potentially useful provisions for community-wide planning for protection of life and property from wildfire; the other codes do not.

4.2.1.5. Discussion

In light of the disastrous 2003 fire season in Southern California a closer examination of current and proposed policies, as well as existing and proposed codes and standards is certainly warranted. This is especially true since one of the major factors affecting the amount of damage sustained by communities and the number of lives lost was the proximity of dwellings to open space. In the case of the Cedar Fire (San Diego County), much of these "open space" lands had not been maintained but were left in a "*natural*" setting. In many areas, the open space wove in and out of developed areas, forming a path of flammable vegetation to developed areas.

In terms of new sub-divisions proposed to be built in the UWI/"Open Space", required fuel/vegetation removal should be included in the "impacts" when conducting an Economic Impact Report (EIR). Similarly, the California Environmental Quality Act (CEQA) needs to be amended to include the impact on a community if a wildfire endangers the surrounding neighborhood/subdivision.

In terms of the existing codes, PRC Section 4291, as well as Appendix II-A of the UFC has proven inadequate to meet the challenge of the UWI fire hazard. Neither have any provisions for fire hardening of structures, other than 4291's provision for reducing the amount of defensible space if the structure is of non-combustible construction. Both sections only address "defensible space" and even then give the AHJ no rational basis for arriving at a rational size for a defensible space zone.

Also, if Section 4291 applies to an area in question, Section 51184 of the Government Code relieves owners of unimproved parcels of any responsibility for maintaining clearance from structures on the other side of the property line. However, it is apparent that undeveloped parcels lacking vegetation management can readily provide a conduit for fire to transition from a burning wildland area into an adjacent urban interface. Furthermore, while Appendix II-A addresses the property line situation, the local jurisdiction must specifically adopt Appendix II-A in their local ordinance for it to be enforceable.

Neither standard provides a framework for modifying the required defensible space based on aspect, fuel/vegetation type, or slope other than a general statement that the AHJ may require greater defensible space (up to 100 feet) if the conditions warrant the increase. It is clear that these one dimensional prescriptive [code] provisions do not work in the UWI zone. Even given flat ground, a 30-foot defensible space zone around a structure is not going to suffice to protect the structure if there is 12-foot pyrophitic vegetation just outside the 30-foot zone.

In contrast, the UWIC at least provides a framework to conduct a rational analysis of both potential and existing building sites to determine defensible space and ignition resistance in new construction, and defensible space requirements in the case of existing structures. However, it does not go far enough. The "ignition resistance" cited in the UWIC is based on resistance to fire penetration for a given time; i.e., a 1-hour rated assembly per a wall-furnace test such as ASTM E-119. This does not address surface flame spread characteristics much less functional ignition resistance. "Ignition Resistance" in the UWIC should be based on resistance to ignition and fire growth, not a "fire rating" developed to assess the fire endurance of interior building components.

As recent fire history shows, neither defensible space/access/water supply, nor ignition resistance construction/building standards can be applied in a vacuum. They need to be used in conjunction with each other to adequately address the urban-wildland interface problem.

Furthermore, in the case of proposed sub-divisions in the UWI, fire-modeling taking into account weather, slope, aspect, fuel types, etc needs to be conducted in order to rationally determine the required fuel modification and ignition resistance of structures. Similar fire modeling is currently done to develop information for firefighters on the fire-line to predict for example expected flame lengths and spotting potential, for firefighter viability and control/extinguishment methods; i.e., direct attack, back burning, etc. The same methods should be applied to determine the ignition potential of structures based on the proposed ignition resistance of the structure's building elements, adjacent fuel types and configuration, etc. Based on this modeling, appropriate fuel modification and/or changes to the ignition resistance of the structures could be made to increase the chances of the structures' survival in a wildland fire event.

4.2.2. Quality Issues at the Urban Wildland Interface

Definitions of construction quality can vary widely depending largely on the context in which they are developed. Where fire safety of new construction in UWI areas is concerned, quality issues frequently relate less to materials used than execution of construction details which can affect the fire performance of a structure. Examples include inclusion of all necessary system components in roofing assemblies –such as appropriate cap sheets and bird screening – as well as their correct installation.

The preceding statements are not intended to downgrade the necessity of using high-quality materials. Rather, like the need to execute construction properly, materials purchased must meet the standards and requirements set out in code-conforming specifications. Without proper execution, a final product cannot be expected to perform so as to meet the basic minimum standard.[35]

Maintenance is a less well-defined issue with respect to compliance with specifications and codes. The inclusion of fire safety features in any design is important. However, no less important is *maintenance* of those features in a code-compliant manner. Such compliance includes a need to replace existing materials and assemblies with similarly-performing components and to successfully maintain construction features such as the minimum quality of defensible space around buildings, fire resistance of roofing materials and assemblies, the quality of screening at vent openings, and removal of combustible debris, such as duff and pine needles from roofs.

4.3. Survivability Evaluation

Earlier, comments were made regarding fire risk and fire hazard as components in a fire safety analysis. In this section, available general information on the nature and level of fire hazards present in these fires as they affect housing stock are evaluated.

4.3.1. Analyses of Damage to Structures by Fire [36]

Cedar Fire

A high percentage of the residences surveyed had pine trees as the predominate form of vegetation, with many of them having less than 10 feet of clearance from the house. There was also a higher incidence of wood-clad exteriors and single-pane windows in the homes affected by the Cedar fire than in the homes affected by the other fires. Furthermore, a high percentage of the homes had roofs covered in composition shingle.

Simi Fire

It has been suggested that the relatively young age of the structures and/or enhanced code enforcement of construction in Ventura County are at least partially responsible for the reduced loss levels in this fire. All of the homes surveyed were constructed during or after the 1970's, which supports the supposition that the relative youth of the structures

[35] It is also of importance to recall that quality issues associated with existing structures in UWI areas are not affected by building code approaches. Such effects were noted in areas such as Lake Arrowhead in the 2003 fires where cabins constructed years ago of ignition susceptible materials which were in close proximity to each other burned readily and were not amenable to fire fighting efforts in spite of manpower that was available.

[36] Because the Piru fire involved so few residences it has not been considered in these analyses.

affected their survival rates. Over half of the homes surveyed had more than 30 feet of clearance from the surrounding vegetation, as well as double-pane windows, stucco cladding, and tile roofing.

Old Fire

In spite of the relatively large number of residences destroyed in this fire limited survey data has been available. Almost all of the homes surveyed in this fire were constructed during or before the 1950s. However, given the age of many of the structures lost and their original construction as primitive cabin and camping sites and vacation retreats, their ready ignition is explicable.

Grand Prix Fire

This fire also extended into the San Bernardino National Forest, which resulted in a low number of residences lost per acre in comparison with the Cedar Fire, which occurred in a more populated environment. This fire occurred near Lake Arrowhead where the design and execution of many of the structures were also consistent with the characteristics of the "vacation retreats" discussed above and in a preceding footnote.

Paradise Fire

The Paradise Fire began on October 26 of 2003 in Valley Center of San Diego County. 56,700 acres were burned, and 231 residences were either destroyed or damaged.

4.3.2. Analyses by Topography

The six fires being reviewed all occurred in areas primarily typified by rugged hillside terrain with extremely low fuel moisture content. The fuels varied from coniferous trees in the San Bernardino Mountains to manzanita and chemise ecology in the San Diego area. Winds varied from onshore Santa Ana winds to the more usual offshore winds coming from the Pacific. In at least one situation onshore Santa Ana winds first pushed fire fronts down-slope in San Bernardino County and later consumed previously unburned fuels as offshore winds pushed fires up previously burned slopes.

Also in San Bernardino County, the Mountain Area Safety Task Force (MAST) provides a good example of an interdisciplinary approach to addressing problems posed by topography, multiple jurisdictions and ecological issues (drought and other issues affecting forest health and fire performance). For further information on this program the reader is

Figure 19: UWI in Everglades in Florida

referred to www. calmast.org /mast/public/index.html.

Overall, it is appears that the wind-driven fires in Southern California in the fall of 2003 were harder to fight when they occurred in mountainous areas. However, wind-driven fires in states like Florida with an essentially flat topography have shown similar fire growth, spread and fire dynamics as the Southern California fires.

4.3.3. Analyses by Building Code under which Projects were Constructed

Potential mitigation of fire hazards in UWI communities involves several different areas which need to be addressed but which are to a considerable extent, mutually exclusive. These include assessing topography and vegetation of the site in question, fire fighting resource availability, and design and features of buildings to be constructed.

There are potentially important interrelationships between these features in terms of predictable performance of a building or a development. However, their mutually exclusive nature - in terms of regulatory issues – means that conventional building codes alone cannot be expected to provide a sufficient regulatory coverage to address potential fire performance in an UWI setting. For this reason an integrated code, such as the UWIC, was developed to incorporate hazard assessment techniques for proposed structures, as well as limited construction guidelines.

Figure 20: UWI fire within NYC limits (photos courtesy of R. Crawford)

The building regulations currently being proposed by the Office of the State Fire Marshal represent the first time that discrete, prescriptive and performance-based construction requirements have been developed for application in such geographic areas. Thus a comprehensive UWI code enforcement approach coupled to mitigation through rational regulation of construction features can be provided for county, community and project levels for review, under which both planning and construction detailing may be addressed.

4.4. County and Community Enforcement Efforts

Discussions of county and city efforts to address UWI mitigation follow:

An illustration of the importance of community enforcement of existing approaches to defensible space regulation follows: In this study, the data available showed that only 24 of the more than 3,600 homes lost in the Southern California Wildland fires of fall, 2003 were located in Ventura County. The fires which occurred there, the Piru and Simi fires did in fact involve lower overall levels of UWI development than the other four fires in the data set. However, there still were numerous dwellings within the perimeters of those fires which were saved according to FEMA's after action reports due to strict vegetation control and maintenance as accomplished by property owners and enforced by the Ventura County Fire Department.

More specifically, building maintenance and enforcement of roofing installation regulations have also been a part of ongoing programs in Ventura County for the last 37 years during which regulations requiring property owners to remove *all* brush and debris within 100 feet of their homes has been strictly enforced. In such cases, if the homeowner chose *not* to comply with those enforcement practices, the county sends contractors to clear the land for them. Subsequently, the homeowner must pay the bill for those clearing activities, which includes a $635 administrative fee. It is of interest that the county has been forced in recent years, to clear only about 30 properties a year out of 15,000 notices that are sent out annually, under the auspices of the Ventura County Board of Supervisors.

Ventura County Fire Department also conducts regular controlled burns, chipping, and aerial spraying to control vegetation growth limiting the available fuels for wildfires. The department also uses animals, such as goats, sheep, and herds of cattle, to remove vegetation from areas that cannot be readily reached by machinery.[37]

In San Diego city a recent update in code enforcement has occurred with adoption of the San Diego Consolidated Fire Code [effective date - November 2001], whereby Appendix IIA of the fire code portion of the California Building Standards Code was adopted and revised to incorporate defensible space and other important definitions relating to clearance of brush, and outdoor fire hazards.

San Diego County also adopted Section 26 text to address construction practices for new projects. However, because this adoption took place so recently, it is not possible to specifically determine the effectiveness of the adopted language.

Another aspect of construction in San Diego County of interest is the performance of older neighborhoods designed to meet earlier versions of model building codes which do not address fire safety in UWI areas. The effects of such fires have been conflagrations; examples of these include the conflagration in Del Mar California, pictured in figure 9, as well as the urban fire spread through affected homes in the Oakland Hills fire over a decade ago.

The preceding performance can be compared to the performance in the East Highlands Subdivision in San Diego County, which was still under construction at the time of the fall 2003 fires. In that case, there were no structures lost (even though some of the unfinished homes were surfaced with exposed building paper), at the time of the 2003 fires. This success was due to building placement, use of appropriate materials, and good pre-planning from a fire safety perspective.

37 "The California Fires Coordination Group: A Report to the Secretary of Homeland Security"; FEMA, 2/13/2004

Figure 21: Housing tract under construction during fall 2003 fires. Note fire damage to surrounding areas, available defensible space and fire deflection walls. Photo Courtesy of R. Crawford

An additional example of a community built under one of the older codes, but with forethought in terms of fire spread is the Hunters Ridge subdivision located north of Fontana in San Bernardino County. In that case, no losses of homes were noted, in spite of nearby wildfire.

4.5 Statistical Evaluation of Building & Site Vulnerability

The collection of detailed information describing many of the 3500+ homes lost in the fall 2003 Southern California wildfires afforded a unique opportunity for analysis. Much of the data available had been collected in effort to - as fully as possible - characterize elements and factors of importance which affected the survivability of the homes affected by the fires. Not surprisingly, that type of specific data was the most useful although large volumes of GIS locator data as well as data on soil conditions after the fires – which are indicative of localized fire intensity, are also available and continue to be correlated with the data on building details.

4.5.1 Synopsis and Summary

This section provides a synopsis for the reader of the detailed materials presented in both the body of the report – which follows - and the appendix. The presentation excludes caveats and qualifications in an attempt to present a quick and clear summary of the analysis and the results. Findings regarding building construction and parcel characteristics can be summarized as follows:

- In general roof materials, window type, eave construction, and vegetation factors appeared to have a considerable impact on the fire performance and survivability of structures exposed in a wildfire.
- In general specific wall materials had little impact on fire performance.
- Roof materials that appeared to **reduce fire risk** are *Tar & Gravel* roofs and *Class A* roofs.
- Eave construction that appeared to **reduce fire risk** is *Short Eaves*.
- Window type that appeared to **reduce fire risk** is *Double Pane* [38].
- Vegetation factors that appeared to **contribute to fire risk** include parcels in areas with *Conifers, Grassland*, and *Heavy Brush.*
- *Defensive Space* appeared to **reduce fire risk** in areas with *Conifers,* and *Grassland.* However, the significance of *Defensive Space* in other landscapes is less certain and may have been confounded both thru interpretation of data collectors and definitional issues.

The following questions have been raised by the analytical process:

- What is the role of decks and porches in the context of fire risk? Preliminary assessments appeared to indicate that some deck and porch constructions actually **reduced fire risk** while other constructions actually **contributed to fire risk**. Given the variety of performances seen and the form of the data collection sheet, this is not surprising.
- What is the role of window frames in the context of fire risk? Preliminary assessments of data collected indicated that *Aluminum Frames* **contribute to fire risk** which is consistent if the data collection treated single glazed aluminum frames differently from those coded as double glazed. The latter category clearly grouped with covariate combinations which reduced the likelihood of building destruction.
- What is the role of topography in the context of fire risk? Preliminary assessments seem to point to the existence of factors that **both contribute to and reduce fire risk**. This is a work in progress in that related GIS and soil destruction data continue to be evaluated.
- What is the role of regional differences in the context of fire risk? Preliminary assessments appeared to indicate **differences in fire risk** exist across regions. For example, the structures located within the perimeter of the Grand Prix fire exhibited **reduced fire risk** as differentiated from homes in other fires. However, it was not possible to identify specific contributing characteristics in that region within the given data set.

4.5.2 Analysis design

Questions developed in creating the detailed analysis which follows included the following: Could material characteristics of a building and its parcel be found to be indicative of its fire performance in the event of a wildfire? If so, to what degree could such characteristics be used to explain the variability in fire performance metrics? How did the fire performance of one given set of characteristics in the data set compare to a

[38] While the data collection forms included a field for annealed glass, only 0.8% of the buildings were noted as having such "safety glazing" which suggests that data gatherers had difficulty discerning annealed glass types which are known to effect glazing survivability.

different group of characteristics? The answers to such questions - if they could be obtained - are certainly of interest to policy makers, insurance companies, construction and materials companies, homeowners, and all others who have a vested interest in managing the risk posed to public safety and property by wildfires.

4.5.3 Data Available and Data Set Used

The project team had access to two primary large data sets, representing information collected concerning approximately 1900 sites within the fire area. Of those two data sets, one essentially included GIS locations for 900 structures along with property value information by GIS locations. Because that data set did not include detailed information concerning physical characteristics of buildings and sites themselves, that information was, unfortunately, discarded.

The second large data set consisted of 989 “observations” with each “observation” being a set of information taken by the OSFM data-gathering team for a single site, which included notations describing up two 104 characteristics at that site. These 989 “observations” encompassed about 1200 structures and the resulting data cleansing activities – discussed below – resulted in a data set of 884 individual locations being evaluated. The observations reflected an attempt by data gatherers to systematize information about each individual parcel surveyed including the structures of importance located at each parcel. All of the observations gathered were located within the perimeter of one of the fires listed initially in this report. That population is defined, in all cases by the fact that every individual in the population was subjected to conditions that typify wildfires in Southern California.

This second large data set posed challenges that merit discussion many of which are characteristic of what might be called an uncontrolled study in that the data was collected before an experimental design was developed. It is useful to conceptualize the observations as being “selected” in two phases. The fire “selected” parcels in the first phase; the project team then “selected” a subset of the parcels that were affected [“selected”] by the fire. The main concern is that little is known about how and why the project team selected the parcels that are in the data set.

Thus, it became important early on to note shortcomings of the original data set These were *primarily* handled by omitting data and by employing assumptions about the remaining observations. Both types of responses – omitting data and employing assumptions - are an integral part of the analysis and as such model interpretations were given context by the liberties that were taken during the data preparation phase of the analysis. For the reader’s interest, a copy of the form used to gather data on-on site for this second data set can be found in the appendix VI.

General treatments that were applied to the data -- sometimes known as data cleansing -- are provided in the table below. Examples of *specific* treatments made on a case-by-case basis are included in the appendix for review by interested readers.

In overview it is our observation that given the magnitude of the loss and the importance in collecting this time sensitive data a great deal of useful information was collected in particular when one considers that the eventual method of analysis used - *binomial family* *generalized linear regression with a logit link function* – was not known to those who directed the data gathering effort. The following discussion addresses issues which developed in utilizing the data gathered:

There were differences from individual to individual evaluating the homes lost, often dwellings in question were so badly burned that detailed information on materials or designs such as type of roofing material, attic venting or eave designs could not be determined. Also, on occasion, a single GIS site locator [signifying a single " observation"] might be used to describe a compound which included numerous units, e.g. summer camps or a religious retreats site.

Data Set Characteristic	Response	Possible Problem Source	Comments
Different data collection forms were used across fire regions	Considerable amounts of time were spent corroborating information source so that variables reflected the same type of information across fires. Additionally, some variables which were available for the Cedar Fire were omitted since this variable couldn't be established across all fires.	Lack of cooperation/communication across agencies. Lack of interagency standards or protocol.	For example, *H20 Supply Type* was not available as a variable in the Grand Prix Fire. As a result, this variable was omitted from the analysis altogether.
Data collection forms contained blank fields	In this case the variable was either omitted or assumptions were imposed allowing the variable to be kept.	Uncertain.	A field which contains "N/A" is much more informative than a blank field; it signals to the analyst that the variable was acknowledged by the data collector. I am not sure why some fields were left blank.
Data entry format varied across data collectors.	Reformat the entire data set. This was a manual, labor intensive process. However, it was also instructive as an exploratory exercise.	It is possible that the data collection templates were considered too restrictive once the process of data collection was underway. The predefined formats were probably abandoned so that additional information could be included.	The additional information was welcomed, but incorporating it was time consuming. For example, latitude and longitude was presented in 3 formats. Wall constructions occurred in combinations of a few types, but the entries were entered as text rather than a numerical code. This resulted in multiple type descriptions for a single type.
Variables and Values weren't defined.	Appeal to authorities for a definition.	Data collectors may have assumed that the entries were self explanatory.	One solution might be to include the contact information of the individuals that supervised the data collection so that they can assist with problems such as this one.

Table 2 – Observations on Information Taken or Discarded from the Original Data Set. Challenges presented by the data set increased "costs" expended to use the data. Omitting data from the analysis meant that data collection resources would have been wasted. Also, a considerable amount of time was dedicated to preparing the data for analysis. Both factors increased the cost of obtaining a 'useable' data source. Cost in this context is used to describe efforts expended to render data collected usable.

The data cleansing process was assisted by input from investigators and other experts and references found in subject matter literature throughout the analytical process. The goal of these consultations was to gain intuition concerning factors that experts deem significant. (For further discussions of such processes, see [39] [40] [41] [42] [43] [44]).

[39] California Dept. of Forestry (1980). Fire Safe Guides for Residential Development in California.

The construction of the data set from the raw data used in the analysis was accomplished by incorporating such "expert opinion" when possible and invoking statistical arguments when appropriate. After this process, the final data set consisted of 884 observations and 40 binary variables. The single response variable indicated whether or not the field staff characterized the structure as a "total loss". The remaining 39 explanatory variables corresponded to structure and parcel features as described below. In that table, the 39 explanatory variables are listed at the left and examples of individual observations – "CN1-CN6" are provided. The data set in fact includes 884 of these data sets of binary variables as noted by "Observation ID" in the examples below:

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[40] Campbell, W. Governor's Blue Ribbon Fire Commission

[41] Graham, H. W., Urban Wildland Fire: Pebble Beach, CA, May 31, 1987, *USFA Fire Investigation: Technical Report Series*. TriData Corporation.

[42] F Northern BAER Team, Department of Interior. Soil Burn Severity for BAER for the Cedar Fires, California (IC #CACNF3056). http://map.sdsu.edu/firenet/new_metadata/soils.html.

[43] William, F. A. (1982), Urban and Wildland Fire Phenomenology, *Prog. Energy Combustion.* Set 1982, Vol. 8 pp. 317-354.

[44] Wilson, R. (1962). The Los Angeles Conflagration of 1961: The Devil Wind and Wood Shingles, *NFPA Quarterly,* January, 1962.

	Observation ID	CN1	CN2	CN3	CN4	CN6
	Covariate Class Information Gathered	• DefSpace • CompShing • HeavyBrush	• DefSpace • DefAction • CompShing • Conifer • Deck • DoublePane • WoodEave	• DefSpace • CompShing • HeavyBrush • Conifer • Deck	• DefSpace • CompShing • HeavyBrush • Conifer	• DefSpace • CompShing • Conifer
Response Variable	**TotalLoss**	0	0	1	1	1
Structure Type	**Mobile**	0	0	0	0	0
	MotorTrav	0	0	0	0	0
Parcel Clutter	**Outbuilding**	0	0	0	0	0
	ManyVehicles	0	0	0	0	0
Defense	**DefSpace**	1	1	1	1	1
	DefAction	0	1	0	0	0
Roof Type	**ClassA**	0	0	0	0	0
	ClassB	0	0	0	0	0
	Wood	0	0	0	0	0
	CompShing	1	1	1	1	1
	TarGrav	0	0	0	0	0
	Masonry	0	0	0	0	0
	AsphShing	0	0	0	0	0
	Metal	0	0	0	0	0
Vegetation Type	**Landscape**	0	0	0	0	0
	HeavyOrn	0	0	0	0	0
	Grassland	0	0	0	0	0
	HeavyBrush	1	0	1	1	0
	NonConifer	0	0	0	0	0
	Conifer	0	1	1	1	1
Wall Type	**Stucco**	0	0	0	0	0
	Wood	1	1	1	0	0
	Metal	0	0	0	0	0
	Masonry	0	0	0	0	0
	T111	0	0	0	0	0
Deck/Porch Attributes	**Deck**	0	1	1	0	0
	Unenclosed	0	0	0	0	0
	NonWood	0	0	0	0	0
Window/Frame Type	**DoublePane**	0	1	0	0	0
	Tempered	0	0	0	0	0
	AlumReVinyl	0	0	0	0	0
	Alum	0	0	0	0	0
	Vinyl	0	0	0	0	0
	Wood	0	0	0	0	0
	Skylight	0	0	0	0	0
Eave Type	**Short**	0	0	0	0	0
	Open	0	0	0	0	0
	Boxed	0	0	0	0	0
	Wood	0	1	0	0	0

Table 3 – Exemplar "Observations" with significant information about variables noted by "1"[45]. This subset of the data set that was used in a regression analysis.

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[45] Note that the designation "CN" indicates the original control number in the data gathered for a particular parcel

The difficulties that arise from the manner in which the data was developed persist despite the efforts of the author and the domain experts to rationalize problematic aspects of the data set. A primary concern is that little is know about why the data-gathering team chose to omit some parcels in the assessment and include others. Before examining some of the technical problems with the data collection process, it is instructive to review the background for the data collection procedure.

The data collection process was conducted primarily by 17 Certified Fire Investigators employed by the Office of the California State Fire Marshal. These individuals have as a primary responsibility, the investigation of cause and origin of individual structural fires in homes, businesses and factories throughout the state of California. They are most highly trained and certified as forensic evaluators and less so in areas such as discriminating between individual classes of products such as different types of composition shingles or other construction materials. However, these investigators are data collection professionals by training.

The investigators were part of a damage assessment effort which began a few weeks after the fires were contained to collect features of parcels and structures which exhibited ignition. Note that this is different than their usual function, which involves reporting the possible causes of ignition of a given isolated fire incident. Such a report of the possible causes of ignition would normally only contain structure and parcel features that the expert deems relevant to that investigation. In the present case the work tasks two inspect the parcel and structure for features that are predefined; features are recorded irrespective of the investigators opinion on whether that feature represented an ignition factor. However, in this case the investigator was also responsible for determining which parcels and structures exhibited ignition and which did not and to what degree, they were damaged which doubtless was reflected in some of the subjectivity of the data.

4.5.4 Discussion

The model for the data set developed is more easily conceptualized when it presents important information regarding the variables in question as shown in the tables below. [The appendix presents further comments and a more detailed review of statistical issues and methods.]

Covariate Class	# in Covariate Class	Probability of "Total Loss"
*****ALL CLASSES*****	883	0.83
CompShing & **Conifer** & MasonryWall & **Alum**	6	0.99
CompShing & **Conifer** & Stucco & **Alum**	26	0.99
CompShing & **Conifer** & WoodWall & **Alum**	38	0.99
CompShing & **Conifer** & Stucco	7	0.96
Conifer	8	0.93
Metal & **HeavyBrush** & MetaWalll & **Deck** & **Alum**	6	0.92
CompShing & WoodWall	19	0.87
GP & **HeavyBrush**	10	0.81
GP	14	0.60

DefSpace & **ClassA** & Grassland & **HeavyBrush** & nonConifer & **Deck** & **Alum** & Open & WoodEave	1	0.29
GP & **MasonryRoof** & Stucco & **Short** & Boxed	5	0.20
DefAction & **HeavyBrush** & **DoublePane** & Skylight & Open	1	0.18
GP & **MasonryRoof** & Landscape & Stucco & WoodWall & **Deck** & Unenclosed & **DoublePane** & Boxed	3	0.10
GP & **TarGrav** & Landscape & Stucco & **Short** & Boxed	1	0.03
GP & **TarGrav** & nonConifer & Stucco & **Short**	1	0.03
GP & **DefAction** & **MasonryRoof** & Stucco & **Short**	1	0.02

Table 4 – Effects of Grouped Variables Types Survivability of Homes. Covariate classes above are presented in terms of the variables that define them. The bold font indicates a statistically significant variable. Note that the number in each covariate class is a lower bound. If we are only interested in the covariate classes in terms of their significant variables the number of covariate classes will become smaller and the number of observations per covariate class becomes larger. There were a total of 420 covariate classes.

What does the data in the table above tell us? First of all, we know that for all classes of variables, the analysis of a total of 883 observations shows the probability of 0.83 [83%] that one observation chosen at random would be a total loss.

Looking at the following line, we see that a total of six homes included a combination of composition shingle roofing, conifers nearby, masonry wall surfaces and aluminum single glazed windows and that the probability of these six homes being with in the homes destroyed was 0.99 [99%]. Note also from the table that the variable "masonry wall" is not illustrated in bold face indicating that the nature of that wall material was not statistically significant. This is an interesting finding of the study in general , which reflects the fact that wall materials themselves whether combustible or noncombustible were not statistically significant, but rather combinations of features added to survivability of buildings.

Looking down the table further, the variable "GP" shows up in a significant number of covariate classes. This abbreviation stands for "Grand Prix" and indicates that the statistical analysis showed that of all the homes in the data gathered, the homes exposed to fire conditions located within the boundaries of the Grand Prix fire displayed a 60% likelihood of being destroyed irregardless of all other factors. Note that this is lower than an observation chosen at random from the data set – 83%.

Looking at combinations of factors which correlated with the survival of individual homes [ie those which were less likely to be destroyed], we note that the occurrence of defensible space at a fire site along with shortened eaves and multiple paned glazing systems as well as tar and gravel or masonry roofing contributed disproportionately to building survival

How does the model fits the data? To answer this question, it was useful to compare the predicted number of structures categorized as a "total loss" in the data set by covariate class (calculated by using the model coefficients presented in the table in the appendix) with the actual number of structures categorized as a "total loss" per covariate class (taken directly from the data set). Those results are presented below:

Covariate Class	Predicted # "Total Loss"	Actual # "Total Loss"
Mobile & **DefSpace** & HeavyOrn	46.8	49
CompShing & **Conifer** & WoodWall & **Alum**	37.6	37
CompShing & **Conifer** & WoodWall	18.4	17
Conifer	7.5	7
CompShing & **HeavyBrush** & WoodWall & **Alum**	5.9	6
Paradise & MetalRoof & MetalWall	3.1	4
CompShing & **HeavyBrush** & WoodWall & **Masonry** & **Alum**	2.0	2
GP & **Short** & Boxed	0.4	1
MotorTrav & Grassland & **Conifer**	0.9	1
GP & **Short** & Boxed	0.4	1
DefSpace & **DefAction** & **ClassA** & **CompShing** & **HeavyBrush** & Stucco & **Deck** & **DoublePane** & Vinyl & Open & WoodEave	0.03	0

Table 5 – A comparison of predicted and actual values. Note that the actual values can only be integers but the predicted values are often fractions.

Thus, for the buildings within the data set, those having defensible space as a noted variable, 49 were recorded as total losses while the model predicted that 46.8 would be lost in a hypothetical fire set of the same characteristics as the fire from which the data was derived.

4.5.5 Comments

A more detailed evaluation of the data set is continuing and it is anticipated that a more detailed version of the data will be published in a peer reviewed format in the near future. As such attempts are being made to draw further inferences from variables such as observations by GIS locator correlated with (a) soil burn damage data available from San Diego State University and (b) elevation and derived topographic data regarding sites of the effected structures.

The benefits of the analysis results achieved to date however are several: The data clearly confirm that real effects deriving from construction detail data exist can be measured and are significant. Likewise, architectural details such as eave design and landscaping issues such as defensible space demonstrate statistical significance as do effects of brush and brush type.

This sort of approach represents a potentially rich area for further analysis. This can be achieved in part refining the way in which data are to be gathered as well as the actual analytical designs used to gather that data. In terms of a first effort, the results are promising and suggest that further efforts be expended to collect similar but more refined data from similar fire incidents – even if not as large as the fires of Fall 2003 - in the future.

4.6. Construction Features Analyses and Case Studies

With increasing certainty it has become evident that a variety of construction features impact the fire performance of buildings constructed in UWI areas. This conclusion is supported by the statistical data presented in the preceding section. This section addresses individual construction features and/or related details.

For many years it has been accepted that features such as wood shake and shingle roofs contribute disproportionately to fire spread in such areas. However, the roles of other construction features whose roles are significant to building survivability in foreseeable UWI fire incidents has become more generally known in the past two decades.

Consistent with this, the fires of 2003 provided a comprehensive data set which includes a feature of great value from a post fire - safety evaluation perspective – the ability to compare destroyed buildings with exemplar analogs which were not destroyed.

This is consistent with forensic situations, in which undamaged exemplars are routinely used to study fire growth and spread patterns which affected damaged structures. In the present case, sufficient numbers of buildings were also fire damaged, *but not completely destroyed*, so that they provided a significant database from which fire spread mechanisms could be documented which would have been lost if those same buildings had been totally destroyed. For perhaps the first time, significant amounts of underlying data are now available to support conclusions on fire growth patterns in the field from other than previously available anecdotal perspectives.

In this section, examples of both [a.] general fire spread characteristics in conjunction with building designs and site location, as well as [b.] specific fire spread characteristics, based on the presence or absence of specific features, are presented. In addition, these are linked to the proposed regulations as well to assess their potential utility

4.6.1. Background

While wildland fires may reach localized temperatures in excess of 1500°F, they are generally less of a threat to the integrity of building constructions than fires which originate routinely inside homes. These take place within the confined spaces of a building and when fully developed, exhibit fire properties - in terms of temperatures and thermal radiation - which are substantially more intense than foreseeable ground fire or brand fire related conditions affecting buildings under UWI scenarios. Conversely, except in the most extreme conditions or under the influence of extreme amounts of brush and/or a lack of defensible space, wildland fire exposures tend to be relatively brief when compared to interior fires, which affect building products and construction assemblies.

For these reasons, the focus in dealing with construction related UWI fire problems tends to be on resistance to sustained ignition of construction assemblies as opposed to fire endurance once a structure has become ignited.

Not surprisingly by having the current data set available, definite mechanisms for fire involvement have been identified for the building elements discussed here as illustrated in the discussion of FMEA techniques presented earlier. As noted there, while to the uninitiated it may seem that buildings in a well-developed UWI incident simply explode,

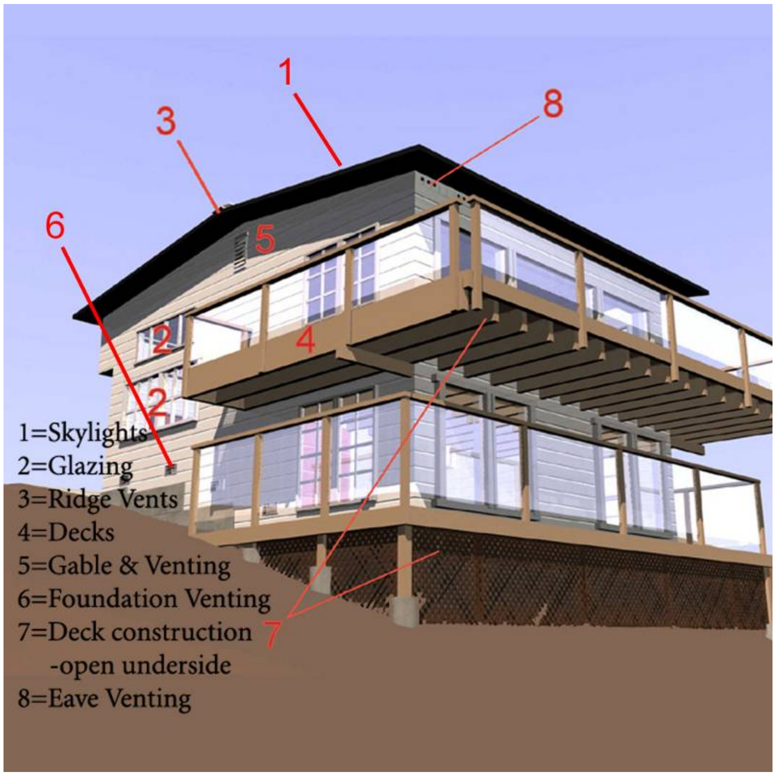

Figure 22: Key features as seen from a downhill view.

Figure 23: Key features as seen from an uphill view.

that is not the case. Rather, whenever a building is lost, a definite chain of events do occur. Thus in both research and development practice as well as post fire analytical methods such as failure modes and effects analysis [“FMEA”] can be used to model such processes

In terms of fire development, UWI events typically result from localized ignition by a single brand, multiple burning brands, adjacent landscaping or other materials through extended radiant exposure of buildings. Subsequently, these initial fires grow and spread causing downstream ignition of cladding materials or the breaking of windows followed by the eventual ignition of the building interior.

The most typical scenario, for example, is one in which construction features are exposed to wind blown burning brands initially, which precede a wind-driven fire front. In such cases, increasing numbers of brands are produced as the fire front passes by a structure.

A well-designed and maintained building will resist these brands or even ignition by the fire front itself. In this way, if there is no avenue into the building for either burning brands or significant heat transfer as by radiation, the building is more than likely to survive.

The generalized views of a hillside home design can be seen in fig 22 and 23. Specific construction features influencing fire performance of such homes are listed in the figures.

4.6.2. Southern California Case Studies

Figure 24: Single-family dwelling. (Photo courtesy of R. Crawford.)

The case studies presented here are drawn from 900 cases reviewed from the over 3500 losses during the 2003 Southern California Wildfires. These illustrate *in a general sense*, how typical building losses occurred – or did not occur – due to construction and site related features in the recent Southern California fires[46]. They have been chosen to illustrate the linked sets of events [chains of events] necessary to sustain the fire loss of a given structure, which in most cases could be traced to burning brands or embers igniting an exterior construction feature or traveling into a structure and igniting fuels there. All the cases described below can be seen in more detail in Appendix II.

In figure 24, a single-story wood sided dwelling is shown, which was built and maintained with a high level of defensible space. What can be seen is that restricted areas of combustible vegetation remote from the structure, while having burned, did not have an impact on the home's survival.

The next case, figure 25, is a stucco clad home, with limited combustible vegetation surrounding it. The home was fire damaged, but not destroyed when an exterior wood deck was ignited by a burning brand. While building areas above the deck were fire

Figure 25: Stucco-sided residence in Cedar fire. Ref Cedar 1003.

46 Additional case studies where specific construction features have been identified as being involved in building performance are included in subsequent sections of text.

damaged, and the potential for fire spread into the attic was great, the chain of events leading to that consequence was not completed and this residence was not lost.

In figure 26, burning external objects attacked this dwelling in the area toward the lower right of this photograph. Wood siding ignited and eventually burned through and, in addition, single- glazed windows broke and fire spread occurred either through attic gable vents above a window or possibly at frieze blocking. This is corroborated by loss of siding materials enclosing the attic area.

Figure 26:Ref Cedar 1009

In figure 27, fire spread to materials stored adjacent to the wood siding. The debris suggests that a wood pile may have been located adjacent to this building and that, flaming as from a brand, began there. Next the wall adjacent to the wood pile ignited causing subsequent ignition of building eaves and possibly nearby brush. Due to intervention efforts and lack of spread to the interior of the building in the initial phases of the fire, this structure was not lost.

Figure 27: Ref Cedar 9081.

Figure 28: Ref Old 10-7

In figures 28 and 29, fire spread from building site to building site assisted by heavy brush, site topography and a lack of defensible space. The combination of these factors led to destruction of clusters of homes.

Figure 29: Ref Old 10-8

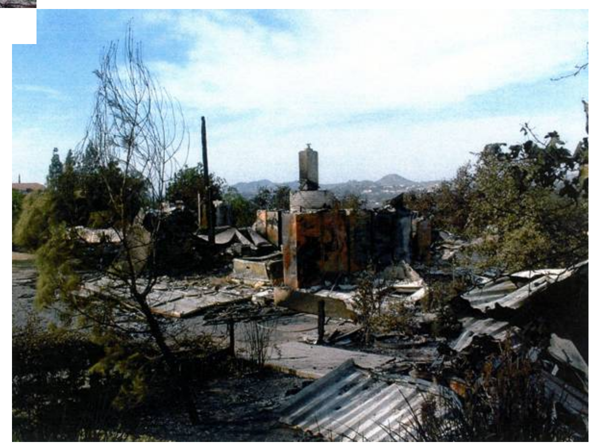

Figure 30: Ref Paradise 121

The residence seen in figure 30 included a tile roof and stucco walls and was completely destroyed in the Paradise fire. It included 15 ft. of defensible space. However, based on available information, an absence of burned vegetation in the direct vicinity of the residence, as well as the presence of an undamaged home at the left rear of the photograph, suggest that the damage to this residence was the result of flying brands or embers.

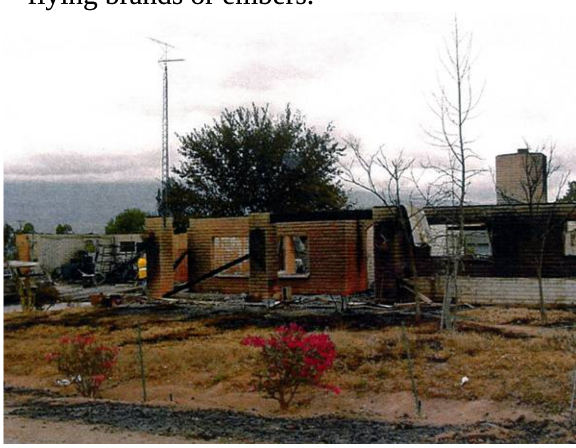

Figure 31: Ref Paradise 201

The home seen in figure 31 was also destroyed in the Paradise fire, The dead grass in the immediate vicinity of the home as well as several trees, provided a ready fuel bed for embers or brands. The collapsed tile roof and non combustible walls indicate that embers became trapped in the eaves or attic space then ignited the residence from the inside.

Figure 32 and 33 are particularly interesting in that they illustrate the benefits of adequate defensible space, properties of combustible siding and how such siding can respond in the presence of strong radiative heat transfer. These photos also demonstrate how the chain of events potentially leading to destruction of a particular building will <u>not</u> be completed if a single element is missing.

Figure 32: Ref Old 1a

Figure 32 shows the gable end of a one-story wood clad ranch house, which facing into a growth of burning manzanita – chemise brush became charred but did not ignite. An important factor here was the defensible space between the brush and the building and the essentially complete absence of plant materials on the ground. The charred area/radiation pattern is reflective of the vertical fire plume, which had been present during the incident.

Figure 33: Ref Old 1b

Figure 33 shows that the fire exposure, while intense was confined to the gable end of this building and that healthy shrubbery survived the fire around the corner from the charred building end.

The photo in figure 34 illustrates the impact and size of defensible space in the rear of the home.

Figure 34: Ref Old 1 c

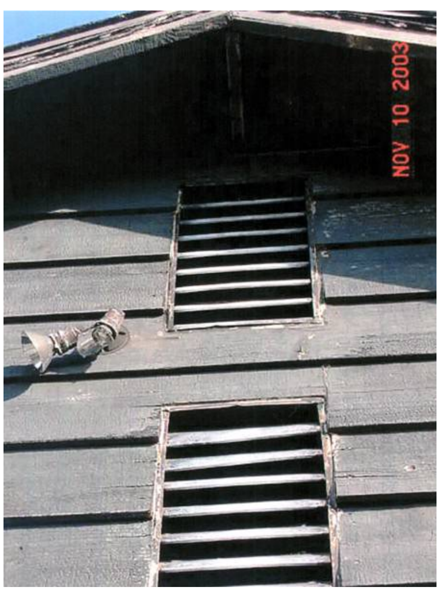

Figure 35: Ref Old 1 d

The photo in figure 35 shows the condition of gable and vents, which, in the presence of wind driven burning brands would have been expected to lead to ignition both at the charred wood surfaces and possibly within the attic space. The absence of ignition of this preheated wood suggests that no materials to pilot ignition at the wood surface were present. That role that would normally be fulfilled by airborne brands and/or burning embers.

4.6.3. Specific Construction Elements

The schematic below illustrates construction elements whose performance has been demonstrated as being critical to building survival in UWI fire situations. Those demonstrations include both conclusions drawn from comprehensive after action reporting as reviewed earlier as well as the inferences which can be drawn from statistical interpretations of that data.

Consistent with this, the proposed regulations include standards for testing and pass/fail performance criteria of such critical construction elements commonly used in the design and fabrication of buildings in UWI areas. In the following sections these classes of elements/assemblies, whose performance has proven critical to building survival, are discussed.

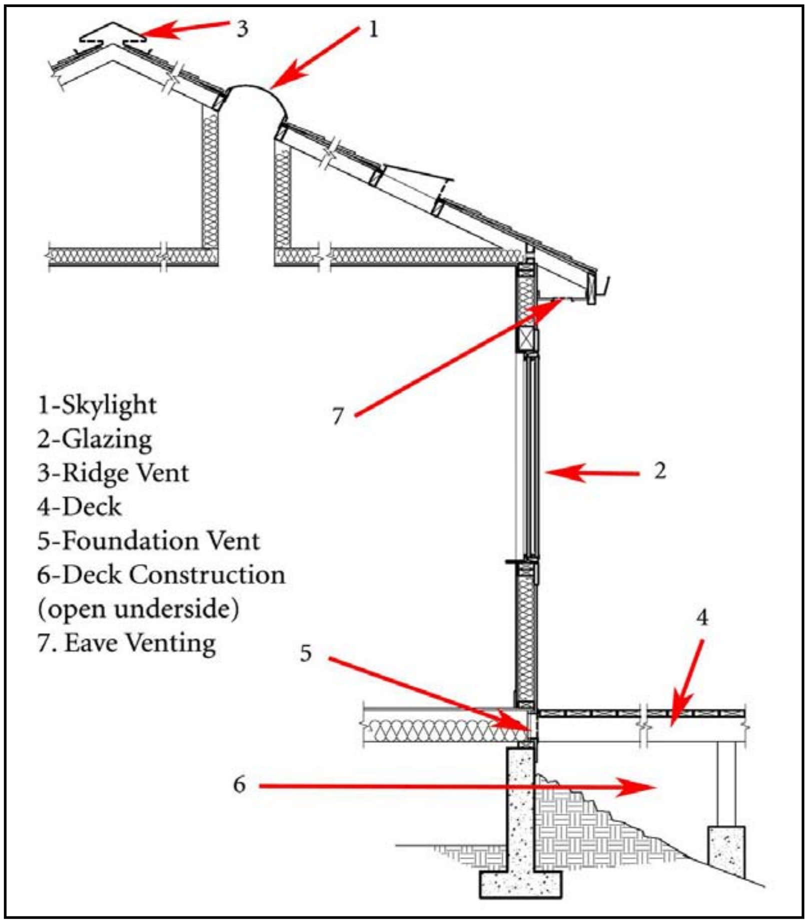

Figure 36: Schematic of Building Section

4.6.3.1. Exterior Walls

There are numerous types and combinations of cladding and structural elements, which are components in an exterior wall system. These can include sheathing of several types (i.e. wood materials based on plywood, OSB Board or lumber as well as gypsum sheathing) and sidings of many sorts including both combustible and functionally non-combustible options[47]. Several of these combinations are illustrated in the figure which follows.

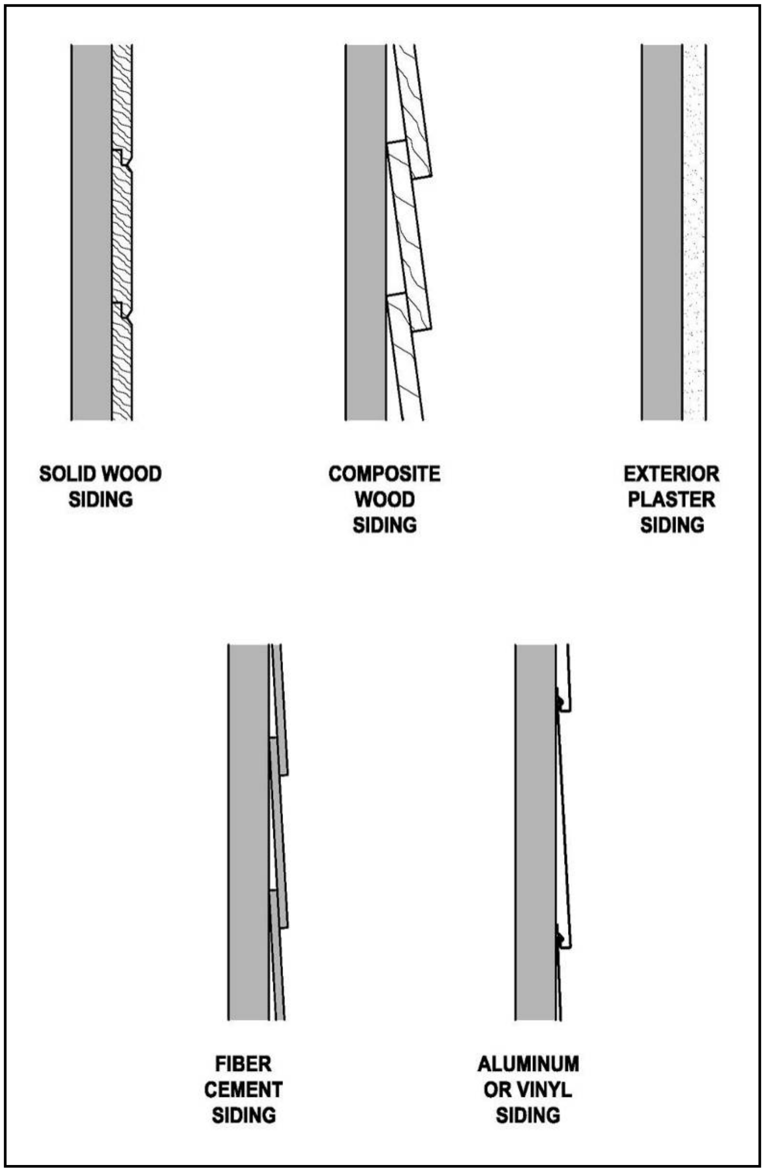

Figure 37: Examples of exterior walls.

Trends describing siding materials types used in currently available survey data are shown in the following table:

[47] The commentary on the proposed SFM standard for testing of walls provides a good in depth review of critical variables in wall performance under foreseeable UWI based scenarios. That commentary can be found at http://osfm.fire.ca.gov.

Principal Type of Exterior Wall Material of New One-Family Houses Completed

(Components may not add to totals because of rounding. Percents computed from unrounded figures.)

Year	Number of houses (in thousands)							Percent distribution						
	Total	Brick	Wood	Stucco	Vinyl siding	Aluminum siding	Other[1]	Total	Brick	Wood	Stucco	Vinyl siding	Aluminum siding	Other[1]
							West							
1973	253	15	87	115	(NA)	(S)	35	100	6	34	45	(NA)	(S)	14
1974	191	14	76	76	(NA)	3	23	100	7	40	40	(NA)	2	12
1975	182	15	75	73	(NA)	3	16	100	8	41	40	(NA)	2	9
1976	232	14	100	103	(NA)	4	11	100	6	43	44	(NA)	2	5
1977	311	21	134	135	(NA)	4	16	100	7	43	44	(NA)	1	5
1978	357	23	160	146	(NA)	6	22	100	6	45	41	(NA)	2	6
1979	337	19	158	131	(NA)	7	22	100	6	47	39	(NA)	2	7
1980	233	14	107	92	(NA)	6	14	100	6	46	40	(NA)	3	6
1981	183	12	86	69	(NA)	6	10	100	6	47	37	(NA)	3	6
1982	121	12	60	39	(NA)	3	7	100	10	49	32	(NA)	2	6
1983	200	13	96	74	(NA)	8	10	100	6	48	37	(NA)	4	5
1984	233	8	101	104	(NA)	7	12	100	3	43	45	(NA)	3	5
1985	239	6	103	110	(NA)	10	11	100	3	43	46	(NA)	4	4
1986	253	6	108	120	(NA)	10	8	100	3	43	48	(NA)	4	3
1987	259	6	103	133	(NA)	9	8	100	2	40	52	(NA)	3	3
1988	248	6	100	132	(NA)	5	6	100	2	40	53	(NA)	2	2
1989	257	6	92	149	(NA)	5	5	100	2	36	58	(NA)	2	2
1990	255	6	105	132	(NA)	5	6	100	2	41	52	(NA)	2	2
1991	205	5	91	96	(NA)	7	6	100	3	44	47	(NA)	3	3
1992	232	9	99	107	3	10	4	100	4	43	46	1	4	2
1993	247	8	112	109	6	10	3	100	3	45	44	2	4	1
1994	285	10	120	131	10	9	5	100	4	42	46	3	3	2
1995	253	6	98	126	13	4	6	100	2	39	50	5	2	2
1996	269	8	96	140	16	4	5	100	3	36	52	6	2	2
1997	259	6	84	140	20	(S)	8	100	2	32	54	8	(S)	3
1998	283	5	83	154	27	(S)	11	100	2	29	55	10	(S)	4
1999	310	5	78	171	37	3	17	100	2	25	55	12	1	5
2000	286	4	66	160	40	2	15	100	1	23	56	14	1	5
2001	303	4	59	178	33	1	27	100	1	20	59	11	(Z)	9
2002	325	3	55	199	35	1	32	100	1	17	61	11	(Z)	10
2003	363	5	42	230	40	2	44	100	1	12	63	11	(Z)	12
RSE	2	37	23	9	25	32	23	(NA)	(NA)	(NA)	(NA)	(NA)	(NA)	(NA)

- Represents zero. A Represents an RSE that is greater than or equal to 100 or could not be computec
NA Not available. RSE Relative Standard Error.
S Withheld because estimate did not meet publication standards on the basis of response rate, associated standard error, or a consistency reviev
Z Less than 500 units or less than 0.5 percent

[1]Includes cinder block, stone, fiber cement, and other types. Data prior to 1992 include vinyl siding.

Note: Single-family estimates prior to 1999 include an upward adjustment of 3.3 percent made to account for
structures built in permit-issuing areas without permit authorization

In terms of behavior in the proposed fire test protocols for exterior walls, a wide variety of combinations of currently used materials have shown acceptable performance.

The availability of such successful systems using commonly available materials is important because exterior walls can contribute to the destruction of a building by at least two principal mechanisms: These include (i) ignition followed by flame penetration into a building through an affected wall or (ii) by wall ignition from a nearby fuel followed by sequential ignition of other construction elements.

In either case, flame spread along the wall surface - even a noncombustible wall surface such as stucco or fiber cement siding - can take place if the igniter flame is sufficiently large. For example, adjacent burning objects such as shrubs may create a large enough flame body or flame plume to create sufficient hot gases to enter building voids (such as attic vents) or fracture window glazing.

Figure 38: Ref Cedar 6069

Combustible wall surfaces are rarely, though occasionally, ignited by radiant energy during large fires. More frequently, they are ignited when nearby fuels such as dry landscaping, nearby furnishings or other light combustibles create the requisite fire plume, leading to ignition which is assisted by radiant or convective pre-heating.

Examples of documented cases of varied performance by such wall materials are presented in the following case studies:

In the example seen in figure 38, a burning brand or ember ignited the wood shingle siding causing vertical flame spread, fracturing the window glazing and eventual burn-through of the steel siding. Adjacent walls to the left, most likely of aluminum or steel siding did not ignite and illustrate comparative performance.

Figure 39: Ref Cedar 15002

In the case seen in figure 39, the response of thermoplastic

Figure 40: Ref Grand Prix 15a

vinyl siding installed over polystyrene insulation can be seen. In the absence of sufficient heat flux and or brands to ignite these materials, the siding materials melted and deformed.

In the loss shown in figure 40 and 41, ignition of the building began in the left foreground, which included the garage, and then spread to the stucco clad building to the right. The fire performance of that stucco wall is depicted in the figure 40.

Figure 41: Ref Grand Prix 15b

Figure 42: Ref Paradise 416

The photo in figure 42 illustrates the consumption of a combustible building cladding enhanced by the presence of nearby untrimmed brush.

4.6.3.2. Window glazing

Fracture of glazed window openings can provide ready entry points for fire by brands and embers. Such damaged opening can also allow for enhanced radiant heating of building interiors and contents as when such occurrences are followed by the ignition of window hangings such as draperies. Over the past 10 to 15 years, the role of the glazing in such failures has become better understood.

Initial observations of the impact of multiple glazed windows on fire spread into buildings were made by assessment teams at the Oakland Hills fire. That fire occurred contemporaneously with increasing use of multiple-glazed systems to meet California State energy standards. This trend continues today. In fact, it is virtually impossible now to build a home with extensive use of single glazing and meet still meet the requirements for energy conservation of the **California Building Code.** This provides new homes with a built- in fire safety feature where UWI fire safety is concerned.

Figure 43: Ref Cedar 108-162

The effectiveness of such systems comes from thermal behavior such that the outer layer of a multiple glazed opening may break due to thermal stresses while a cooler inner glazing layer persists due to the lower temperatures present between the layers.

Conversely, single layer glazed windows break readily in the face of either a fire plume from nearby burning materials or intense radiant exposure. Tempered safety glass can also protect a window from easy fracture during a brief period of fire exposure.

Figure 44: Ref Cedar 108-161

In all cases, the variables associated with window frame types needs to be evaluated to ensure that glazing materials remain intact during fire exposure and do not simply fall out of a window frame thus allowing fire to enter the structure.

The photos in figures 43, 44 and 45, show in sequence, the remains of an opening for a glazed sliding door (covered after the fire by plywood) which was ignited by nearby combustibles which themselves had been ignited by a flying brand. Interestingly, one can see the intact tempered safety glass used in the original sash, as well as the burned vinyl frame, which failed thus allowing fire spread into the building as seen in figure 45.

Figure 45: Ref Cedar 108-164

Issues of fire performance of popular vinyl windows have been addressed such that - *with reasonable due diligence applied to window frame fabrication* - successful fire performance by vinyl windows can be demonstrated. Standard of care issues important in this regard are addressed in the document in Appendix III.

Figure 46: Ref Cedar 1034

The photo in figure 46 shows the fire performance of wood shingle trim on the side of a brick clad building, which was ignited by brush below the window. It is unclear whether or not fire breached the windows themselves.

Figure 47: Ref Cedar 3018

Figure 47 depicts fire entry through failed glazing in a stucco wall.

The photo in figure 48 depicts the outline of materials which burned along a stucco-clad wall below a double glazed window opening. In this case the glazing functioned sufficiently to prevent fire from entering the building and did not fail completely, although exterior glazing layers appear to have been compromised. This illustrates a positive attribute of multiple glazed windows.

Figure 48: Ref Cedar 5093

Figure 49:Ref Cedar 212

Figure 49 depicts the thermal failure of window trim without loss of the double glazed materials involved. Note the breakage of the glazing layer at the right.

Figure 50 depicts PVC window and door frame following thermal failure of the frame elements. This photo underscores the need for vinyl windows with framing element detailing, which remain intact during a low intensity fire exposure.

Figure 50: PVC Window and door frame after thermal failure. Photo courtesy of R. Crawford.

4.6.3.3. Soffitts, eaves and rain gutters

Construction and configuration of soffitts, eaves and rain gutters must be addressed because their failure will contribute disproportionately to the penetration of an exterior fire to the interior of a dwelling.

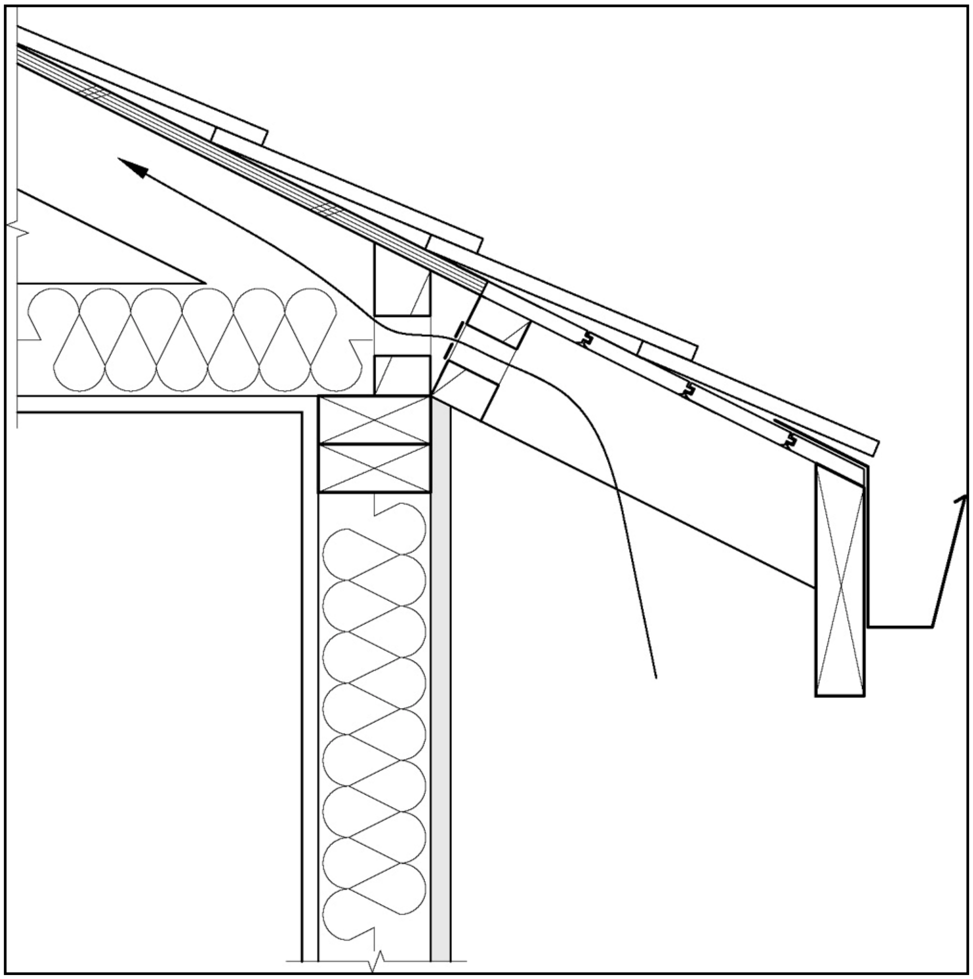

Figure 51: Open soffitt design showing the expected air flow pattern through vent which is part of an extended eave design

Figures 51 and 52 show open soffit designs intended to promote good air flow into attics. Conversely, a closed soffit design can be seen in the multi-element drawing (figure 36), which preceded this discussion. Such closed designs can prevent or reduce flame penetration into attics, and interior building spaces.

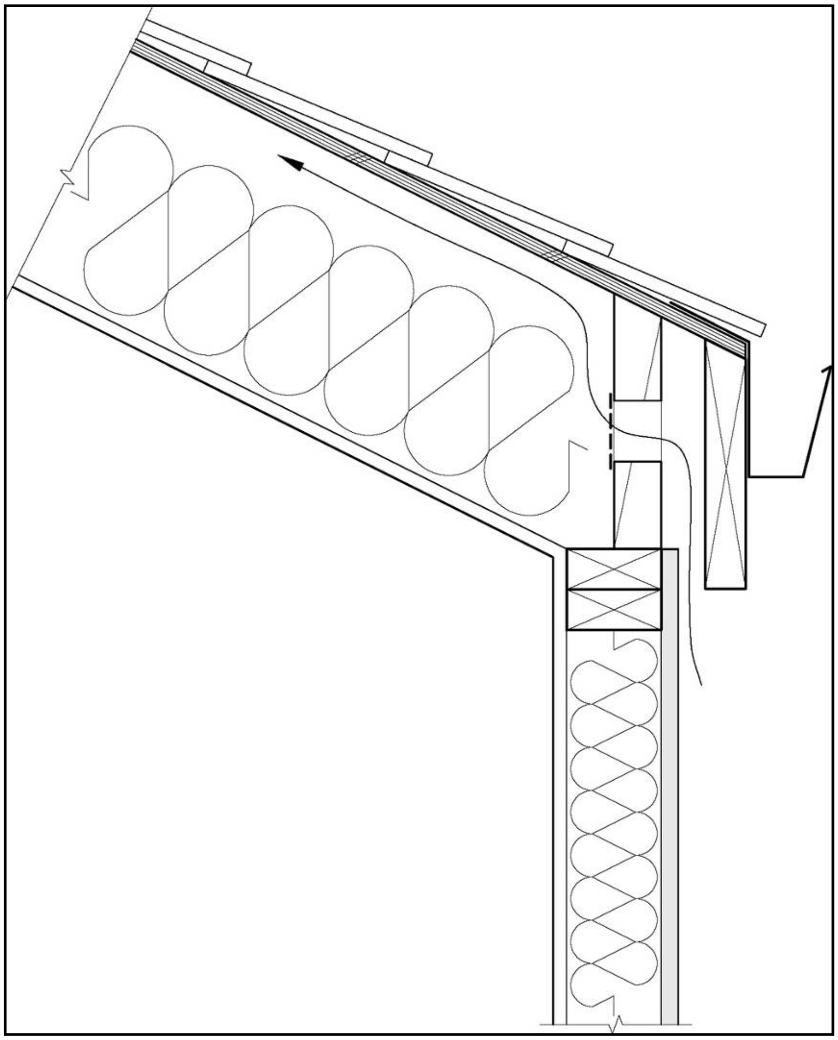

Figure 52: Foreshortened eave design showing air flow pattern.

The fire performances of soffitt designs are important because they can become collection points for flames and concentrate the destructive effects of a flame body on a building envelope.

Similarly eaves, more frequently than not include vents in the form of necessary screened openings which provide interior ventilation to building attics. Unfortunately these openings also allow for ready penetration of fire into dry, preheated wood framed attics which potentially lead to fire spread through a dwelling. Likewise, combustible rain gutter materials in the presence of a large flame body contribute to fire growth in eave areas and promote fire movement into attic areas. This is an area that is ripe for innovative design approaches to address both the ventilation needs of buildings and firespread issues.

The photo in figure 53 depicts fire spread along an open eave design which is part of an attached building garage.

Figure 53: Ref Old 21-27

The remains of a ranch home can be seen in figure 54. Note the virtually intact garden on three sides of the home. Eyewitnesses observed burning brands entering the attic of this home, causing its total destruction.

Figure 54: Ref Old 2125

Figure 55: Open Eave Design. Photo courtesy of R. Crawford.

Figures 55 and 56, (overall view and close up) show an open eave design in conjunction with a tile roof which permitted passage of burning embers into a roof deck area. Ignition occurred in this case, but the resulting fire did not destroy the building. This illustrates a problematic aspect of the study of such ignitions which have the potential for creating sustained building ignitions but where, in some cases, only localized fire growth occurs.

Figure 56: Open eave design. Photo courtesy of R. Crawford.

Figure 57: Stucco-covered soffit & eave design. Photo courtesy of R. Crawford.

4.6.3.4. Decks, Balconies, Patios and Patio Covers

Attached, appurtenant structures including *decks, balconies, patios and patio covers* can assist fire entry into dwellings and/or create fuel which in turn yields significant flame bodies that lead to sustained ignitions of buildings.

Designs of decks adequate to survive predetermined insults from either a flame plume from below or a burning brand from above have been researched, developed and successfully tested. Inclusion of these proven design features can reduce fire spread into buildings of which they are part during UWI fires.

Figure 58: Ref Cedar 67-1124

Likewise, balconies and patios with combustible structural elements need to be evaluated to ensure that they do not ignite readily or in the face of foreseeable fire threats will not show sustained ignition. Patio covers tend to provide identifiable fire risks, because they are frequently the first materials to which burning brands flames from nearby burning landscaping or buildings attach themselves. As such, they can provide an unwanted pathway to total building involvement.

Figure 58 shows the fire performance of an attached carport roof deck. This fire was observed to spread from a deck area at photo left, igniting materials under this roof deck, and causing spread into the building through a glazed opening.

Figure 59: Ref Cedar 2106

Figure 59 illustrates the results of ignition of a wood deck due to materials burning from below. The burning of the deck created an avenue for window breakage and direct fire entry into the stucco clad building.

The photo in figure 60 depicts discontinuous burning of a deck constructed with a vulnerable underside and fuel present.

Figure 60:Ref Cedar 5101

Figure 61 illustrates how a fire at ground-level attacked building elements, including a stairway going to a second-level. However, this fire burning at ground-level did not breach the first-floor openings of the building

Figure 62depicts a lack of vertical fire spread from a wood deck composed of tightly fitting wood boards whose particular design prevented spread to the upper surface of the deck and associated building components such as the glazed opening at photo left.

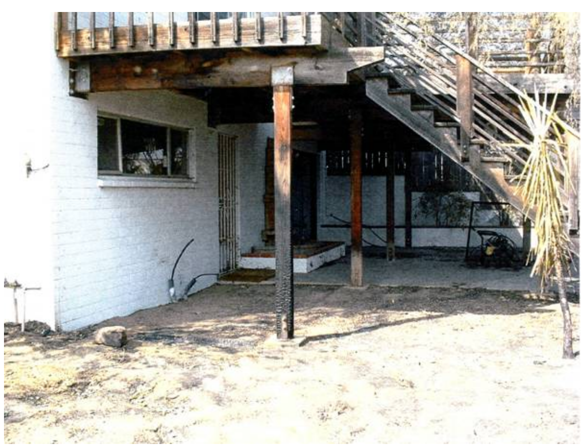

Figure 61: Ref Paradise 111

Figure 62: Ref Cedar 6097

4.6.3.5. Attic and Sub-Floor Openings

Figure 63: Area where the foundation vent was subjected to flame exposure from nearby burning organic matter. Ref Cedar 5102

Attic and sub-floor vent openings were repeatedly noted to have provided pathways into fire affected structures by observers and witnesses to the fires of 2003. Lack of screening or use of screen sizes sufficiently large to provide openings for the passage of burning brands were two means by which fire spread to building interiors in these cases.

Because building ventilation is also an important construction parameter, it is important that eave and attic vent designs be carefully scrutinized, so that sufficient ventilation for building integrity is maintained. Options to affect this include use of eyebrow and ridge vents as well as "active" vent designs based on intumescent technology, which will activate by heat, sealing openings which would otherwise permit passage of burning brands. Such devices have been successfully demonstrated.

Figure 64: Ref Grand Prix 34a

Figure 65: Red Grand Prix 34b

Figure 64 shows the remains of a brick structure with heavy wood beams, which was observed to have embers, which were sucked into the attic spaces prior to building ignition. The overall view of the building can be seen in figure 65.

Finally, the use of turbine ventilators for attics is commonplace inasmuch as they assist in keeping a home cool. However, numerous observations were reported during the fires of 2003 according to which buildings utilizing turbine ventilators caused soffit and gable vents to become entry points for multiple burning brands because of negative pressure occurring in those attics. Such occurrences were observed to lead to losses of structures.

Figure 66: Attic are below turbine vent. Courtesy R. Crawford.

Consistent with observations of embers being drawn into at-risk UWI structures, numerous witnesses specifically reported that spinning turbine ventilators - designed to create negative pressure within attics - encouraged fire involvement there. In figure 66, burned embers were located in a building attic directly beneath such a wind turbine. Apparently the presence of noncombustible insulation prevented ignition in this attic space.

4.6.3.6. Roofing Assemblies

The importance of *roofing assembly* types and their fire performance properties cannot be understated. For many years, a hierarchy of common roofing materials (in terms of fire performance) from non-rated through the most durable [class A roof systems] has been recognized. In fact, as noted earlier, roof covering fire performance was one of the first areas of construction technology addressed in terms of building-to-building fire spread.

Figure 67: Tile roof system. Photo courtesy of R. Crawford

Of interest from a regulatory perspective, however, are recent findings by researchers that while the fire performance of roof coverings themselves are important, roof sheathing and components such as cap sheets play a role in the survivability of roof systems in the face of fire threats associated with flying brands and embers. Thus, performance testing of *complete* roofing assemblies takes on a new importance in areas of high fire hazard, such as at the UWI.

Figure 68:Ref Cedar 105 117

The importance of behavior of entire roofing systems has been stressed in areas such as the Del Rosa complex near San Diego in 2003. In that case, both fire resistant composition and tile roof assemblies were used and both suffered fire damage. Failure due to the absence of sufficient "bird screening" at openings in tile roof elements and worn cap sheets at roofing valleys were noted by post fire observers.

Figure 69:Ref Cedar 105 120

Other examples of roofing assemblies include figures 68and 69 which reflect the not unexpected behavior of an old-style wood shake roof near a state park building.

Figure 70 depicts fire involving a roofing system based on noncombustible tile, which was subject to the intrusion of burning brands and/or embers.

Figure 70: Ref Paradise 410

4.7. Additional Site Issues of Importance

Other areas of importance relating to home design at the UWI exist and are worthy of comment such as fences, outbuildings, landscaping, vegetation clearance, structure location and water supply issues.

4.7.1. Fences and Outbuildings

Fences and outbuildings are known to contribute to fire incidence, particularly where these are composed of combustible materials of small cross-sections, which ignite readily and which are located close enough to facilitate the ignition of buildings.

Figure 71: Depicts a wood fence, which burned and spread fire to an adjoining stucco-clad building. Ref Cedar 7050.

Figure 72: Involvement of wood fencing from a spreading windblown widland fire. Photo courtesy of R. Crawford.

4.7.2. Landscaping

Landscaping represents a crucial element in maintaining defensible space around buildings. Improperly or poorly chosen landscaping may ignite easily, and due to its placement, assist in the penetration of a fire into a dwelling. Considerable literature exists covering this subject. See for example summary data on Fire Mitigation supported in part by the State of California and found at http://nature.berkeley.edu/~fbeall/firemit.html.

4.7.3. Vegetation Clearance

Vegetation clearance around structures is a primary component of importance in the defensible space concept. Maintenance of clearance from vegetation, in conjunction with careful selection of landscaping, is crucial to the survivability of an urban wildland interface dwelling. This is also a mandated requirement under section 4291 of the PRC

4.7.4. Structure Location

Structure location on property relative to setback, surrounding vegetation and proximity to upward and downward slopes is important. If a home is to be located on a sloping site, the importance of landscaping and defensible space considerations increases as the degree of slope increases.

4.7.5. Water Supply Issues

In areas where municipal water supplies do not exist, it is important for homeowners to consider the installation of a private water supply, as well as associated accessories to assist in protecting their property. Water supply- issues related to the use of fire sprinklers, normally associated with suppression of interior fires in residences, need to be considered along with the use of rooftop sprinklers where the operation of the devices will have an impact upon available fire fighting water supplies at a given site.

5. Proposed UWI Building Regulations

The draft UWI building standards [see http://osfm.fire.ca.gov] have been developed to address the kinds of performance discussed and illustrated in the preceding text sections. The importance of those regulations is apparent in that they are directly responsive to demonstrable short-comings in fire performance of the elements they address which are specific to UWI applications. Specific substantiation for the first time of the linkage between fire performance shortcomings of such assemblies to loss of buildings in UWI environments is a key finding of this report.

A statewide task group, encompassing fire safety personnel, representatives of the private sector, fire researchers and representatives of the state fire marshal's office have been involved in the development of these protocols and charging code language. In addition, a task group of the ASTM E-05 committee charged with development of large-scale fire testing standards is overseeing standardization of these test methods as part of an ANSI approved consensus development process.

For the first time, the proposed standards will provide clear and discreet minimum standards for construction of crucial building elements. Their purpose is to increase the ability of structures located within the UWI area *to survive a wildland fire*. The regulations address the fire performance of materials and systems for roofs, exterior walls, doors, eaves, soffitts, glazing elements and decks and are consistent with specific UWI threats, not to more generic by less appropriate performance goals based on existing criteria for fire resistant building assemblies such as generic one hour walls and rated opening protection.

The proposed regulations are supported by significant research results in work conducted at the University of California Fire Forest products laboratory, begun in 1995 and described in the document "**Urban Wildland Interface Building Test Standards**".

The proposed urban wildland interface building test standards include carefully written protocols for the testing of exterior walls and decks, eaves, roof assemblies, and exterior windows. They provide the needed link between the stated – and accepted - need for mitigation of fire threats to dwellings in UWI zones and actual test standards with regulatory capabilities.

6. Other Potential Initiatives Consistent with UWI Fire Mitigation

In conducting the research underlying this report, two potential approaches to further mitigate site-based hazards that threaten defensible space around UWI structures have been noted. These relate to possible initiatives by local regulatory personnel as well as private sector insurance activities. These are discussed below:

6.1. Brush Clearance Funding Sources

Discussions with persons involved with urban wildland interface fire problems continually address the critical role of maintaining adequate defensible space.

In the case of enforcement of applicable local and state regulations, mandating the maintaining of adequate defensible space, funding for enforcement personnel and resources to assure conformance to applicable regulations is an apparent weak point in the majority of fire protection districts.

Jurisdictions such as Ventura county as well as individual cities have had a high level of success in terms of mitigating urban wildland interface fire threats by requiring that property owners maintain defensible space. Their success has frequently been enabled by local regulatory avenues requiring clearance such that local contractors will be called in and paid through tax liens in cases where property owners who are unwilling or unable to properly maintain their property. Thus, a possible avenue to both pay for inspections and for necessary clearing can exist without cost to state or municipal agencies. These observations suggest the need for an initiative at the state level to provide tools such as simple preparation of model ordinances for self-funding of enforcement activities which would include both the cost of inspections as well as clearing activities themselves.

6.2. Insurance Driven Site Modification

Closely related to the subject matter in the item above are initiatives, followed by some insurance companies' actions as part of their underwriting practices for homes located at the urban wildland interface. As such, carriers put homeowners on notice that your homeowners insurance will not be renewed or continued after a reasonable period of time, if appropriate brush clearing activities in conformance with state requirements does not take place.

Programs consistent with this concept have been carried out in the state of Colorado subsequent to urban wildland interface fires there within the past few years with measurable success by State Farm insurance.

Carrying such an approach a step further, might for example, involve development of a program leading to adoption of regulations by the insurance commissioner either;

1. Precluding insuring of properties that do not meet requisite requirements for defensible space or mandating programs by individual insurance carriers or
2. As has been done in the past, when state mandate called for creation of special investigative units to reduce fraud levels associated with arson, create regulatory approaches that require that insurance carriers demonstrably regulate underwriting activities in this area more stringently.

7. Conclusions

The causes, extent and magnitude of fires at the urban wildland interface are reasonably well known and understood. Historical information clearly supports the existence of a high level of fire risk in such areas. Research into the specific mechanisms leading to losses of large numbers of homes and other structures located at the urban wildland interface has been conducted and those results provide direct linkage between inadequate fire performance of specific identified construction elements and losses of homes.

Those results also demonstrate why certain constructions are more successful, and others less successful at surviving UWI fire threats. They also provide practical and attainable measures as guidance in the setting of minimum standards for construction practices in areas identified as very high fire hazard severity zones.

In order to enable development to successfully continue in such areas without creating hazards affecting the safety of persons living there or unacceptable performance levels, appropriate minimum construction standards have been developed to be used in concert with existing requirements for maintenance of defensible space.

Appendix I-Proposed UWI Building Standards

CDF-SFM Draft
Code Change Proposal
Chapter 7A – July 12, 2004

SECTION 701A [For SFM] FIRE-RESISTANT MATERIALS AND CONSTRUCTION METHODS USED WITHIN WILDLAND AREAS

SECTION 701A -- SCOPE
This chapter applies to building materials and systems used in the exterior design and construction of buildings and structures located within:

> A) State Responsibility Areas designated as Very High Fire Hazard Severity Zones by the Director of Forestry and Fire Protection pursuant to Article 9 (commencing with Section 4201) of Chapter 1 of Part 2 of Division 4 of the Public Resources Code.
>
> B) Very High Fire Hazard Severity Zones designated by a local agency pursuant to Chapter 6.8 (commencing with Section 51175) of Part 1 of Division 1 of Title 5 of the Government Code.
>
> C) Urban Wildland Interface Communities and other areas designated by a local agency pursuant to Health & Safety Code 13108.5.

SECTION 702A – PURPOSE

The purpose of this code is to provide minimum standards to increase the ability of a building or structure to resist the intrusion of flame or burning embers through the use of performance and prescriptive requirements in accordance with the authority provided in Government Code §51189 A.

SECTION 703A -- FIRE RESISTANT MATERIALS AND SYSTEMS

703A.1 General.
Materials and systems used for fire-resistant purposes shall be in accordance with this Chapter.

703A.2 Qualification By Testing
Material and material assemblies tested in accordance with the requirements set forth in 704A.3 shall be accepted for use in accordance with the results and conditions of such tests. Testing shall be performed by a testing agency approved by the Authority Having Jurisdiction.

703A.3 Standards of Quality.

The SFM standards listed below are also listed in Chapter 35, Part III and are part of this code. The Authority Having Jurisdiction may use other standards that are equal to or exceed standards listed in this chapter.

The standards listed below are adopted by the State Fire Marshal and are listed in Chapter 35.

SFM-1 EXTERIOR WALL TEST STANDARD
SFM-2 EXTERIOR WINDOW TEST STANDARD
SFM-3 UNDER EAVE TEST STANDARD
SFM-4 ROOF ASSEMBLY TEST STANDARD
SFM-5 DECK TEST STANDARD

SECTION 704A -- ROOFS

704A.1 General.
All roof assemblies shall provide protection in accordance with SFM-4 “Roof Assembly Test Standard” and Chapter 15. This requirement shall also apply to non-combustible roof coverings specified in Chapter 15.

704A.2 Roof Spaces and Openings
For roof coverings where the profile allows a space between the roof covering and roof decking, the spaces shall be constructed to prevent the intrusion of flames and embers.

NOTE: Use of one layer Type 72 ASTM cap sheet shall meet the intent of this section.

704A.3 Roof Valleys
Roof valleys shall be protected with metal flashing having a minimum 36 inch (914 mm) wide underlayment consisting of one layer of Type 72 ASTM cap sheet running the length of the valley.

704A.4 Roof Vents

Roof and attic vents shall resist the intrusion of flame and embers into the attic-area of the structure.

NOTE: Roof and attic vents protected by corrosion resistant and non-combustible screening material with ¼ inch (6 mm) openings shall meet the intent of this section.

704A.5 Eave Protection
Eaves and soffits shall meet the requirements of SFM-3 “Under Eave Test Standard” or shall be protected by materials approved for one-hour fire resistive construction on the exposed underside as approved by the Authority Having Jurisdiction.

704A.6 Skylights
Skylights shall be constructed of tempered glass, multi-layered glazed panels, or those materials approved by the Authority Having Jurisdiction.

EXCEPTION: Structures protected throughout by an approved automatic sprinkler system.

704A.7 Roof Gutters and Downspouts
Roof gutters and downspouts shall be constructed of non-combustible materials.

SECTION 705A – EXTERIOR WALLS

705A.1 General.
All wall assemblies shall provide protection from the intrusion of flames and embers in accordance with SFM-1 "Exterior Wall Test Standard"

EXCEPTIONS:

A. Exterior wall surface material must have an underlayment of ½ inch (12.7 mm) fire rated gypsum sheathing that is tightly butted, or taped and mudded, under 3/8 inch (9.5 mm) plywood or ¾ inch (19 mm) drop siding or an approved alternate. Exterior wall coverings shall extend from the top of the foundation to the underside of the roof sheathing, terminate at 2 inch nominal solid wood blocking between rafters at all roof overhangs, or in the case of enclosed eaves, terminate at the enclosure. The requirements of this exception shall satisfy the intent of Section 705A.1 as an alternate means of protection.

B. Non-combustible material, heavy timber or log wall construction

705A.2 Exterior Wall Openings.
Exterior wall openings shall be in accordance with this section.

705A.2.1 Exterior Glazing
Exterior windows, window walls, glazed doors, and windows within exterior doors shall conform to the performance requirements of SFM-2 "Exterior Window Test Standard." The installation of tempered glass, multilayered glazed panels, glass block or other window assemblies having a fire protection rating of not less than 20 minutes shall meet the intent of this section.

705A.2.2 Doors
Exterior door assemblies shall conform to the performance requirements of SFM-1 "Exterior Wall Test Standard." Alternatively, exterior doors shall be an approved non-combustible construction, solid core wood not less than 1-3/4 inches (44 mm) thick, or have a fire protection rating of not less than 20 minutes to meet the intent of this section.

EXCEPTION: Vehicle access doors.

705A.2.3 Windows within Doors
Windows within doors and glazed doors shall be in accordance with Section 700A.5.2.1.

705A.2.4 Wall Vents

Vent openings in exterior walls shall resist the intrusion of flame and embers into the structure.

NOTE: Vents shall be screened with a corrosion-resistant, non-combustible wire mesh with a ¼ inch (6 mm) opening except where not permitted elsewhere in this code and be a minimum of 10 feet from the property line. Underfloor ventilation openings shall be located as close to the ground as practical. This requirement shall meet the intent of this section.

705A.3 Appendages and Floor Projections
The underside of cantilevered and overhanging floor projections shall maintain the fire resistive integrity of the exterior walls or the projection shall be enclosed to the ground with exterior walls in accordance with Section 705A.2.

705A.4 Unenclosed Underfloor Protection
Buildings or structures shall have all underfloor areas enclosed to the ground with exterior walls in accordance with Section 705A.1.

EXCEPTION: Complete enclosure may be omitted where the underside of all exposed floors and all exposed structural columns, beams and supporting walls are protected as required for exterior one-hour fire resistance rated construction. Heavy timber, 2 inch nominal redwood heartwood, fire retardant treated wood or non-combustible materials shall meet the intent of this section.

706A ANCILLARY STRUCTURES

706A.1 Decking
Decks and similarly constructed horizontal structures within 10 feet of the habitable structure shall comply with the performance requirements set forth in SFM-5 “Deck Test Standard.”

EXCEPTION: Decking of heavy timber, 2 inch nominal redwood heartwood, fire retardant treated wood or non-combustible materials shall meet the intent of this section.

706A.2 Ancillary Structures
All ancillary and detached accessory structures shall comply with the performance requirements set forth in this code as determined by the Authority Having Jurisdiction.

APPENDIX II – California Fire Case Studies
Attic Space/Vents

Incident 1: There is little information concerning the fire incident at this residence

Figure 1: Light combustibles adjacent to house ignited and burned to foundation vents of the house. Fire either self-extinguished or was extinguished before it could enter the home. * Cedar 5102.jpg

Incident 2:

Identifier: Grand Prix 34			
Structure Condition	Total Loss	**Roof Covering/Assembly**	Clay Tile
Construction Type	Type V Fire-Rated	**Wall Construction**	Adobe
Prevailing Vegetation Type	Heavy Ornamental	**Window Glass Type**	Single Pane
Property Line Setback	31-60 feet	**Window Frame Type**	Aluminum
Decade Built	1970	**Vents**	In Attic
Area of Fire Origin	Attic Space	**Eave Construction**	Wood
Form of Ignition	Embers sucked into attic space	**Defensible Space**	0-29 feet

Figure 2: Fire entered structure through vents in the attic, igniting the attic space and spreading throughout the residential structure. Charring to the beams and upper section of the wall is evident. Grand Prix 34 beam.jpg

Figure3: Overall view of residence. Note remaining green shrubbery in front of the residence, which supports this loss being caused by an ember. Grand Prix 34 front.jpg

Vegetation Clearance

Incident 3:

Identifier: Old 1			
Structure Condition	1-10% Damage	**Roof Covering/Assembly**	Comp Shingle
Construction Type	Type V	**Wall Construction**	Wood Siding
Prevailing Vegetation Type	Heavy Brush	**Window Glass Type**	Single Pane
Property Line Setback	61-100 feet	**Window Frame Type**	Aluminum Clad Wood
Decade Built	N/A	**Vents**	NW side
Area of Fire Origin	Exterior Wall	**Eave Construction**	Open Eave
Form of Ignition	Radiant heat	**Defensible Space**	0-29 feet

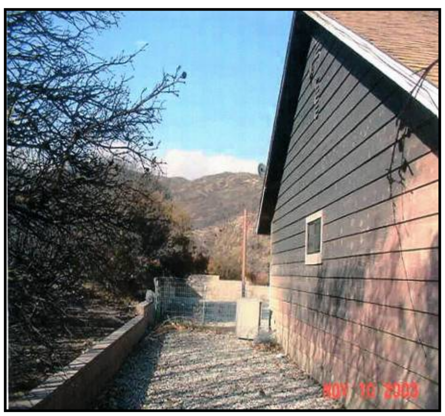

Figure 4: The fire approached the home from the side, with radiation charring the side of the home. However, no ignition occurred. Note the clearance between the vegetation and the home. Reference: Old 1 Exposure. jpg

Figure 5: Adjacent side of home. Undamaged vegetation across cleared space from fire-damaged vegetation. Note lack of damage to south side of home. Reference: Old 1 Front.jpg

Figure 6: This photo depicts the other adjacent side of the home, where the clearance is larger than on the other side of the home. Reference: Old 1 Side.jpg

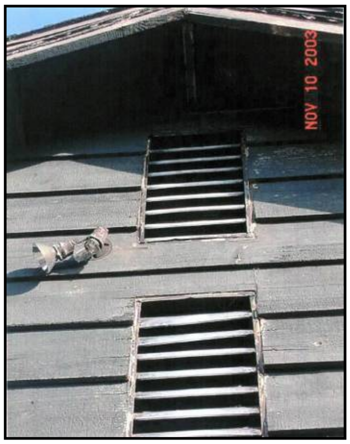

Figure 7: This photo depicts the attic/gable end vents, which sustained heating but did not sustain ignition by either brands or embers. Reference: Old 1 Vent.jpg

Decks/Patios/Patio Covers

Incident 4: There is little information concerning the fire incident at this residence.

Figure 8: The fire began in the foreground of the photo, and then moved across the wood deck, which led to window breakage and ignition of the residence. This was a significant exposure. Note the burned bush near the building in the background of the photo, as compared to undamaged vegetation nearby; suggesting ignition by a brand. *Reference: Cedar 2106.jpg

Figure 9: The fire was a ground fire that moved to the underside of the deck, then burned its way upward. Note the extensive damage to the vertical beams; this implies that the fire was burning for a while before either self-extinguishing or being extinguished. * Cedar 5101.jpg

Figure 10: The fire began under the deck and moved laterally, charring the wood members underneath. The fire then either self-extinguished or was extinguished. * Reference: Cedar 6097.jpg

Incident 5:

Identifier: Cedar 67			
Structure Condition	Total Loss	**Roof Covering/Assembly**	Clay Tile
Construction Type	Type V Not rated	**Wall Construction**	Brick
Prevailing Vegetation Type	Landscape/Heavy Brush	**Window Glass Type**	Single & Double Pane
Property Line Setback	Over 100 feet	**Window Frame Type**	Aluminum
Decade Built	N/A	**Vents**	Mesh vents on all sides
Area of Fire Origin	Deck/Porch	**Eave Construction**	Open Eave
Form of Ignition	N/A	**Defensible Space**	30-100 feet

**Figure 11: The fire came from a northeastern direction according to a neighbor. The fire then ignited the porch and spread across the residence. The remnants of the patio (wood posts with a tile roof) are on the left of the photo, and the carport is in the center of the photograph. Note that the charring to the carport is more severe on the left side, near the patio, suggesting fire travel from the right.
Reference: Cedar 67 1124.jpg**

Incident 6:

Identifier: Paradise 111			
Structure Condition	Total Loss	**Roof Covering/Assembly**	Wood
Area of Fire Origin	Vegetation	**Wall Construction**	Wood
Form of Ignition	Direct Flame	**Defensible Space**	10 feet

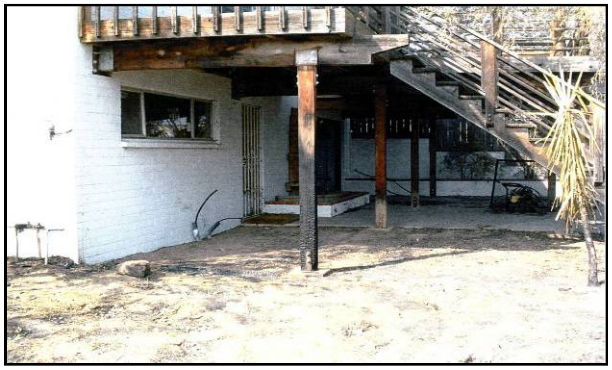

Figure 12: This fire was a ground fire, which moved along vegetation near the residence, eventually igniting the wood post of the deck. Fire either self-extinguished or was extinguished. Reference: Paradise 111.jpg

Eaves

Incident 7:

Identifier: Old 21			
Structure Condition	Total Loss	**Roof Covering/Assembly**	Comp Shingle
Construction Type	Type V Not Rated	**Wall Construction**	Stucco
Prevailing Vegetation Type	Landscape/Grass	**Window Glass Type**	Single Pane
Property Line Setback	21-30 feet	**Window Frame Type**	Aluminum
Decade Built	1950	**Vents**	Sub-floor and Attic
Area of Fire Origin	Exterior Roof/Eaves	**Eave Construction**	Open Wood Eave
Form of Ignition	Brands/Embers	**Defensible Space**	30-100 feet

Figure 13: Fire travel under eaves. Damage to the top of walls and minor damage to roof. Embers and brands coming originated at the property next door, which was completely destroyed. Reference: Old 21 27.jpg

Figure 14: Residence completely destroyed. Note the green grass and the healthy trees in the immediate vicinity of residence; these indicate that a brand or embers, as opposed to direct flame impingement, started the fire. Reference: Old 21 25.jpg

Fence

Incident 8:

Identifier: Cedar 7050			
Structure Condition	Total Loss	**Roof Covering/Assembly**	Comp Shingle
Prevailing Vegetation Type	Pine Forest	**Wall Construction**	Stucco
Defensible Space	5 feet		

Figure 15: This photo depicts fire movement along fence line, causing thermal damage to the edge of the roof of an adjacent residence. Example of fencing providing easy access for fires to move from residence to residence. Reference: Cedar 7050.jpg

General

Incident 9: There is little information concerning the fire incident at this residence.

Figure 16: : This fire began at the deck, probably by a brand. Destroyed the deck and window glazing adjacent, allowing entry of the fire into the residence at glazing opening. Note the well-managed landscaping. Reference: Cedar 1003.jpg

Figure 17: This fire most likely began on the lower right side of the photograph, where it ignited combustible exterior cladding, then moved upward consuming eaves and breaking the single-pane glazing, where fire then appeared to enter the residence through the opening. * Reference: Cedar 1009.jpg

Figure 18: The fire moved from the left of the photograph to ignite the building, most likely igniting a woodpile on the side of the home initially. The woodpile then ignited the side of the wood-clad structure, sending heated gases and embers into the eaves, which spread the fire along the section of the structure. Note the charred area along the top of the structure. * Reference: Cedar 9081.jpg

Incident 10:

Identifier: Old 10			
Structure Condition	Total Loss	**Roof Covering/Assembly**	Comp Shingle
Construction Type	Type II	**Wall Construction**	Concrete Blocks
Prevailing Vegetation Type	Pine Forest	**Window Glass Type**	Double Pane
Property Line Setback	0-5 feet	**Window Frame Type**	Aluminum
Decade Built	1940	**Vents**	N/A
Area of Fire Origin	Interior Space	**Eave Construction**	Open Wood Eave
Form of Ignition	Convective Heat	**Defensible Space**	30-100 feet

Figure 19: This photo depicts a structure that was entirely consumed by a severe fire exposure, as can be seen by the extensive damage to the trees, down to the level of the ground. This may suggest a ground fire that then moved rapidly up slope with trees igniting in a torch-like manner. Reference: Old 10 #7.jpg

Figure 20: This photo depicts the overall effects of the fire in this area, showing extensive damage to all structures in the area. Under this type of fire scenario, enhanced structural features will assist minimally in preventing destruction, but in areas with a high fuel density, ignition may still occur. Note the proximity of the trees and vegetation to the destroyed homes. Reference: Old 10 #8.jpg

Incident 11:

Identifier: Paradise 115			
Structure Condition	Total Loss	**Roof Covering/Assembly**	Metal
Construction Type	Type V	**Wall Construction**	Stucco/Metal
Defensible Space	20 feet		

Figure 21: The fire moved from the right side of the photograph to the structure, spreading most likely by direct flame and by embers, based on the proximity of the structure to the burned trees on the right. Reference: Paradise 115.jpg

Incident 12:

Identifier: Paradise 121			
Structure Condition	Total Loss	**Roof Covering/Assembly**	Spanish Tile
Area of Fire Origin	N/A	**Wall Construction**	Stucco
Form of Ignition	Brands/Embers	**Defensible Space**	15 feet

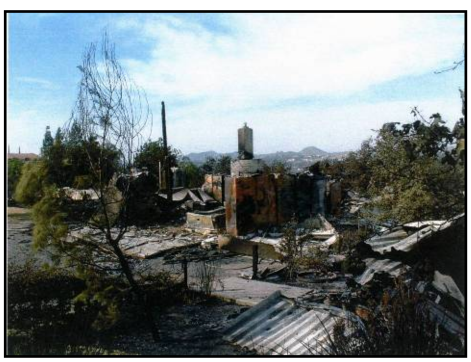

Figure 22: Based on the absence of burned vegetation in the direct vicinity of the residence, as well as the presence of an undamaged home at the left of the photograph, the damage to this residence was the result of brands or embers. Reference: Paradise 121.jpg

Incident 13:

Identifier: Paradise 201			
Structure Condition	Total Loss	**Roof Covering/Assembly**	Tile
Area of Fire Origin	N/A	**Wall Construction**	Stucco
Form of Ignition	Brands/Embers	**Defensible Space**	N/A

Figure 23: The dead grass in the immediate vicinity of the home, as well as several trees, provided a ready fuel bed for embers or brands. The absence of a roof to this residence suggests that embers may have become trapped in the eaves or attic space, then ignited the residence from the inside, causing roof collapse. Reference: Paradise 201.jpg

Incident 14:

Identifier: Paradise 507			
Structure Condition	80% Loss	**Roof Covering/Assembly**	Stucco
Area of Fire Origin	N/A	**Wall Construction**	Stucco/corrugated metal
Form of Ignition	N/A	**Defensible Space**	10 feet

Figure 24: This photo depicts a structure that has been severely damaged by the fire. The top right section of the roof and upper wall is destroyed, suggesting that the fire may have begun from a brand or ember either igniting the roof or becoming trapped underneath the eaves on the front of the structure, igniting the wall and eventually the roof. Reference: Paradise 507.jpg

Glazing & Window Trim

Incident 15: There is little information concerning the fire incident at this residence.

Figure 25: The fire appears to have moved along grass, also igniting ornamental plants. These ignited wood shake trim underneath the window. The heat of the wood shakes burning was sufficient to warp the blinds behind the window, but it does not appear to have cracked the window glazing. In other structures, the burning of this combustible window trim would have cracked the window glazing, possibly allowing entry into the home and leading to complete destruction of the residence. * Reference: Cedar 1034.jpg

Incident 16:

Identifier: Cedar 108			
Structure Condition	1-10% Damage	**Roof Covering/Assembly**	Comp Shingle
Construction Type	Type V Not rated	**Wall Construction**	Stucco
Prevailing Vegetation Type	Ornamental/Grass	**Window Glass Type**	Double Pane
Property Line Setback	31-60 feet	**Window Frame Type**	Vinyl
Decade Built	N/A	**Vents**	N/A
Area of Fire Origin	Sliding Glass Door	**Eave Construction**	Open Eave
Form of Ignition	Flying Brands	**Defensible Space**	30-100 feet

Figure 26: In this photo, sooting from hot gases exiting the sliding door is apparent above the boards currently sealing the residence. The abundance of healthy grass in the foreground of the photo suggests that the fire was not ground-based, but rather brand- or ember-based, followed by structural failure of the window.
Reference: Cedar 108 pix 162.jpg

Figure 27: This photo depicts the interior of the same residence behind the boards shown in the previous photograph. The incoming fire appears to have ignited a drape that hung on the right side of the sliding glass door, which then led to ignition of other items in the interior of the home. Cedar 108 pix 164.jpg

Incident 17: There is little information concerning the fire incident at this residence.

Figure 28: This fire initiated at ground level, but the heat was sufficient to break through the window glazing, allowing for entry into the residence. Note the intact brush in the background of the photograph. *
Reference: Cedar 3018.jpg

Incident 18: There is little information concerning the fire incident at this residence.

Figure 29: This burn pattern was produced by a light combustible in close proximity to the residence, which either self-extinguished or was extinguished before it could completely penetrate the window glazing. Note that one layer of the window glazing is cracked, but that the blinds behind the window do not appear to be warped or melted significantly. * Reference: Cedar 5093.jpg

Incident 19: There is little information concerning the fire incident at this residence.

Figure 30: This photograph depicts fire-damaged window trim with cracked window glazing. The glazing is double-pane, which prevented the fire from entering the residence as the window frame burned. * Reference: Cedar Saved 212

Roof Materials and Assemblies

Incident 20:

Identifier: Cedar 105			
Structure Condition	Total Loss	**Roof Covering/Assembly**	Untreated Wood Shake
Construction Type	Type III	**Wall Construction**	Rock/Concrete
Prevailing Vegetation Type	Grass, Brush, Oak, and Pine	**Window Glass Type**	Single Pane
Property Line Setback	N/A	**Window Frame Type**	Wood
Decade Built	1920	**Vents**	N/A
Area of Fire Origin	Exterior Roof	**Eave Construction**	N/A
Form of Ignition	Flying Brands	**Defensible Space**	0-29 feet

Figure 31: This photograph depicts the Cuyamaca Park headquarters and museum. There is heavy damage to the front of the building, and no roof left. Note the proximity of the vegetation to the structure.
Reference: Cedar 105 pix 117.jpg

Figure 32: The wood shake roof to the Cuyamaca Park headquarters and museum was completely consumed in the fire, as can be seen in the photograph. It is interesting to note that the surrounding vegetation is relatively undamaged, with the exception of scorch marks on the trunk of the tree in the foreground where gases were venting out of the adjacent window. Reference: Cedar 105 pix 120.jpg

Incident 21:

Identifier: Paradise 410			
Structure Condition	20% Damage	**Roof Covering/Assembly**	Tile
Area of Fire Origin	Roof	**Wall Construction**	Stucco
Form of Ignition	Ember/Brand	**Defensible Space**	5 feet

Figure 33: Embers' effect on the roof of the structure in the foreground, causing ignition under the eaves. Reference: Paradise 410.jpg

Exterior Wall

Incident 22:

Identifier: Cedar 15002			
Structure Condition	1-10% Damage	**Roof Covering/Assembly**	Comp Shingle
Area of Fire Origin	N/A	**Wall Construction**	Siding
Form of Ignition	Convective Heating	**Defensible Space**	10 feet

Figure 34: This home did not ignite, but convective and radiant heating by the fire front occurred. This caused the warping of the siding on the exterior cladding. Reference: Cedar 15002.jpg

Incident 23: There is little information concerning the fire incident at this residence.

Figure 35: This photograph demonstrates the difference in performance between different cladding materials. The area on the left appears to be clad in aluminum or steel siding, which remained intact. The area on the right, however, was clad with wood shake, which did not withstand ignite. There is dead grass surrounding the residence, which contributed to the fire, and most likely ignited the wood shake. * Reference: Cedar 6093.jpg

Incident 24:

Identifier: Grand Prix 15			
Structure Condition	Total Loss	**Roof Covering/Assembly**	Concrete Tile
Construction Type	Type V Not Rated	**Wall Construction**	T-111
Prevailing Vegetation Type	Heavy Ornamental	**Window Glass Type**	Single Pane
Property Line Setback	0-5 feet	**Window Frame Type**	Aluminum
Decade Built	1980	**Vents**	Louvers on both sides
Area of Fire Origin	Exterior Wall	**Eave Construction**	Boxed
Form of Ignition	Direct Flame	**Defensible Space**	0-29 feet

Figure 36: The home in the foreground was completely destroyed. Two nearby structures, however, appear only to have suffered radiant heat damage as well as some direct flame damage, but no ignition. Reference: Grand Prix 15.jpg

Figure 37 This photo depicts a closer view of a wall adjacent to the destroyed structure. This wall suffered surface damage only. Reference: Grand Prix 15 Close.jpg

Incident 25:

Identifier: Paradise 416			
Structure Condition	25% Damage	**Roof Covering/Assembly**	N/A
Area of Fire Origin	Exterior Wall	**Wall Construction**	N/A
Form of Ignition	Brand/Ember	**Defensible Space**	N/A

Figure 38: This structure suffered severe damage to the exterior, but it does not appear to have spread to, and destroyed the interior. Nearby vegetation is undamaged, which implies brand or ember ignition.
Reference: Paradise 416.jpg

Appendix III-Fire Performance of Vinyl Windows.

Rancho Santa Fe Fire Protection District
PO Box 410 / 16936 El Fuego
Rancho Santa Fe, CA 92067
(858) 756-5971

County of San Diego
Department of Planning and Land Use, Building Division
5201 Ruffin Road, Suite B, San Diego, CA 92123 (858) 565-5920

August 24, 2001

Advanced Window Technology
4966 Santa Monica Avenue, Suite A
San Diego, CA 92107

Dear Vinyl Window Retailer:

In May if this year we sent your company the enclosed letter stating that due to the wildland fire hazard and public safety concerns, vinyl window assemblies were not acceptable for use in homes within wildland/urban interface areas. Recently, the Forest Products Laboratory at U.C. Berkeley completed extensive testing of vinyl windows to determine their performance in the wildland/urban interface environment. Tests have concluded that vinyl window assemblies containing certain characteristics performed satisfactorily for use within these areas.

Based on this information, vinyl window assemblies are now acceptable for use within wildland/urban interface areas in the County of San Diego (unincorporated areas) and Rancho Santa Fe Fire Protection District, as long as the windows have the following characteristics:

1. Frame and sash are comprised of vinyl material with welded corners.
2. Metal reinforcement in the interlock area.
3. Frame and sash profiles are certified in AAMA Lineal Certification Program (Verified with either an AAMA product label or Certified Products Directory)
4. Certified and labeled to ANSI / AAMA / NWWDA 101/I.S.2-97 for Structural requirements.
5. Glazed with insulating glass, annealed or tempered.

Vinyl window assemblies that do not contain these characteristics are still not acceptable within local wildland/urban interface areas.

In order to verify each window meets the aforementioned five characteristics, vinyl window assemblies must be properly labeled. In addition, the specification sheets for these windows should be made available to window purchasers to show fire inspectors at final inspection; this will help us ensure the permissible windows have been installed.

Thank you for your time and consideration in regards to this safety matter.

Respectfully,

Erwin L. Willis, Fire Chief
Rancho Santa Fe Fire Department
(858) 756-5971

Clifford F. Hunter, Fire Code Specialist
Building Division, County of San Diego
Department of Planning and Land Use
(858) 694-2951

Appendix IV- Statistical Analysis Appendices

1. Data Gathering form.

CODE PERFORMANCE EVALUATION FORM

FIRE NAME:____________________

FOUNDATION NUMBER					GPS WAYPOINT NUMBER						
ADDRESS NUMBER					STREET NAME						
ADDITIONAL LOCATION INFO (on corner, on ridge, other observations)											
LATITUDE					LONGITUDE						
TOWNSHIP					RANGE						
OCCUPANT NAME					OWNER NAME						
INSURANCE CARRIER											
STRUCTURE TYPE (circle one)	HOUSE	CABIN	DUPLEX	APART-MENT	MOBILE HOME	MOTOR HOME	TRAVEL TRAILER	WARE-HOUSE	OTHER		
CONSTRUCTION TYPE (circle one)	TYPE I	TYPE II	TYPE III	TYPE IV	TYPE V		FIRE RATED?		OTHER		
OCCUPANCY TYPE (please specify)	A	B	C	E	F	H	I	M	R	S	U
TYPE OF BUSINESS (if applicable)											
PROPERTY USE (circle one)	1-2 FAMILY	MULTI-FAMILY	BOARD OR CARE FAC.	DORM OR BARRACK	HOTEL OR MOTEL	INDUSTRIAL	AGRICULT-URAL	SCHOOL	CHURCH	OTHER	
# OF DWELLINGS THIS LOCATION (enter numbers)		# DAMAGED		# DEST-ROYED		# SAVED					
OUTBUILDINGS AFFECTED (enter numbers)		# DAMAGED		# DEST-ROYED		# SAVED					
VEHICLES AFFECTED (enter numbers)		# DAMAGED		# DEST-ROYED		# SAVED					
STRUCTURE CONDITION (circle one)	TOTAL LOSS	50-99% DAMAGE	11-49% DAMAGE	1-10% DAMAGE	NO DAMAGE						
STRUCTURE STATUS AT FIRE TIME (circle one)	OCCUPIED	EVACU-ATED	VACANT								
DEFENSIBLE SPACE (circle one)	NONE	0-29 FEET	30-100 FEET	100-200 FEET	OVER 200 FEET	UNKNOWN					
DEFENSIVE ACTIONS TAKEN? (circle one)	YES	NO	UNKNOWN	IF YES, BY WHOM?							
ROOF COVERING/ASSEMBLY (circle one)	CLASS A	CLASS B	CLASS C	UNTREAT-ED WOOD	TREATED WOOD	COMP SHINGLE	BUILT-UP	CLAY TILE	CONCRETE TILE	OTHER	
GROUND FLOOR DIMENSIONS (enter values)	LENGTH IN FEET		WIDTH IN FEET								
NUMBER OF STORIES (enter number)											
CONSTRUCTION QUALITY (best judgement - circle one)	CUSTOM	ABOVE AVERAGE	AVERAGE	SUB-STANDARD	OTHER						
YEAR BUILT (enter year)											
PROPERTY MANAGEMENT (circle one)	PRIVATE TAX	PRIVATE NON-TAX	FEDERAL	STATE	COUNTY	CITY	OTHER				
CASUALTIES THIS LOCATION (enter values)	CIVILIAN INJURIES		CIVILIAN DEATHS		FIREFIGHTR INJURIES		FIREFIGHTR DEATHS				
AREA OF FIRE ORIGIN (circle one)	EXTERIOR ROOF	EXTERIOR WALL	EXTERIOR DOOR	DECK-PORCH-ETC	CRAWL SPACE	ATTIC SPACE	INTERIOR SPACE	UNKNOWN	OTHER		
LEVEL OF CERTAINTY (circle one)	CERTAIN	ALMOST CERTAIN	PROBABLE	BEST ESTIMATE		*INFO SOURCE*	WITNESS	PHYSICAL EVIDENCE	CIRCUMS-TANTIAL	OTHER	
FORM OF HEAT OF IGNITION (circle one)	DIRECT FLAME	CONVEC-TIVE HEAT	FLYING BRANDS	DEPOSITED EMBERS	RADIANT HEAT	UNKOWN	OTHER				
LEVEL OF CERTAINTY (circle one)	CERTAIN	ALMOST CERTAIN	PROBABLE	BEST ESTIMATE		*INFO SOURCE*	WITNESS	PHYSICAL EVIDENCE	CIRCUMS-TANTIAL	OTHER	
STRUCTURAL FACTORS CONTRIB TO IGNITION (circle one)	ROOF	WALLS / SIDING	WINDOWS / DOORS	VENTS	EAVES	VALLEYS / CORNERS	DECK / PORCH	FENCE	OTHER / EXPLAIN		

Photo Log: Roll #______ Frame #______

CODE PERFORMANCE EVALUATION FORM

FIRE NAME:______________________

VEGETATION FACTORS (circle one or more)	TOO CLOSE TO HOUSE	DROUGHT STRESSED	DEAD / DYING	DEBRIS ON ROOF	DEBRIS ON GROUND	DEBRIS IN RAINGUTTR			
LOGISTICAL FACTORS (circle one or more)	ADEQUATE ACCESS	POOR ACCESS	NO ACCESS	LOCKED GATE	OTHER OBSTACLE	HUMAN OBSTACLE	UNSAFE FOR CREW		
ENVIRONMENTAL FACTORS (circle one or more)	HIGH WIND	HIGH HEAT	LOW HUMIDITY	ROUGH TERRAIN	STEEP TERRAIN				
OPERATIONAL FACTORS (circle one or more and enter notes)	NO H2O SUPPLY	LOW H2O FLOW	NO H20 FLOW	STAFF SHORTAGE	EQUIP SHORTAGE	EQUIP FAILURE	**H20 SUPPLY TYPE & CONDITION AFTER FIRE**		
LOCATION SLOPE (circle one and enter observations if any)	FLAT-MILD 0 9.9%	MILD-MED 10-19.9%	MED-MOD 20-39.9%	MOD-EXTR 40%+	NOTES				
PROPERTY LINE SETBACK (circle one)	0-5 FEET	6-10 FEET	11-20 FEET	21-30 FEET	31-60 FEET	61-100 FEET	OVER 100 FEET		
ADJACENT STRUCTURE SETBACK (circle one)	0-5 FEET	6-10 FEET	11-20 FEET	21-30 FEET	31-60 FEET	61-100 FEET	OVER 100 FEET		
PREVAILING VEGETATION TYPE (circle one)	LAND-SCAPE	HEAVY ORNAMNTL	GRASS-LAND	HEAVY BRUSH	OAK WOODLND	PINE FOREST	OTHER		
VEGETATION CONDITION (circle one or more)	HEALTHY	IRRIGATED	DISEASED	OVER-GROWN	DYING	DEAD	OTHER		
ACCESS ROADS (enter values or indicate yes/no)	GRADE %		TOTAL WIDTH		ONE WAY?		DEAD END?		TURN-AROUND?
DRIVEWAYS (enter values or indicate yes/no)	GRADE %		TOTAL WIDTH		VERTICAL CLEARNCE		PASSING LANES?		TURN-AROUND?
WALL CONSTRUCTION (enter material type and assembly notes)									
DECK/PORCH (enter location, material type & assembly notes)									
WINDOW GLASS TYPE (circle one or more)	SINGLE PANE	DOUBLE PANE	TEMPERED	ANNEALED	GLAZED	UNKNOWN	OTHER NOTES		
WINDOW FRAME TYPE (circle one ore more)	ALUMINUM CLAD WOOD	ALUMINUM REINF VINYL	ALUMINUM	FIBER-GLASS	VINYL CLAD WOOD	VINYL	WOOD	OTHER	
ATTIC AND SUBFLOOR VENTS (enter descriptions & locations)									
SKYLIGHT CONSTRUCTION (enter yes/no, value, and constr. type)	SKYLIGHT PRESENT?		SURFACE AREA		TYPE (see windows)				
DOOR CONSTRUCTION (enter descriptions)	SLIDING GLASS TYPE			FRENCH TYPE			OTHER TYPE(S)		
EAVE CONSTRUCTION (circle one or more and enter value)	OPEN EAVE	BOXED EAVE	WOOD	VINYL	OTHER TYPE				OVERHANG WIDTH
RAIN GUTTER CONSTRUCTION (circle one)	STEEL	ALUMINUM	VINYL	OPEN TOP	SCREENED TOP	CLOSED TOP	OTHER NOTES		
BUILDING IDENTIFICATION (circle one ore more and enter values)	ADDRESS PRESENT	VISIBLE FROM ROAD	CONTRAST-ING	LETTER HEIGHT		LETTER WIDTH		STROKE WIDTH	
GREENBELT OR FUELBREAK (circle if present & enter values and notes)	PRESENT	WIDTH		LENGTH		OBSERVE EFFECT			
TYPE OF WATER SUPPLY SYSTEM (circle one)	MUNICIPAL	PRIVATE	WELL	OTHER					
FIRE SPRINKLERS (circle one or more & enter type and notes)	PRESENT	INTERIOR	EXTERIOR	TYPE				NOTES	

COMMENTS/NOTES/OBSERVATIONS

____

____

Photo Log: Roll #______ Frame #______

2. Individual Data Element Cleansing Examples

Obs or **Var**	**Problem**	**Action**	**Justification**
Obs = *CN43*	50 structures correspond to one observation	Created 50 observations	All 50 structures are mobile homes. The variables don't account for the differences one might expect to find in a sample of mobile homes, i.e. the problem of assigning the proper variable value to the proper mobile home doesn't exist since all mobile homes are described in the same fashion in terms of the variables that are available.
Obs = *CN63*	20 structures correspond to one observation	Omit	There is no way to determine which of the variables correspond to a given structure.
Obs = *CNGP033*	Structure is a hay barn	Omit	This type of structure is likely to have much different fire performance than a residence. There are only a few of these structure types in the data.
Obs = *CN14*	Parcel contained 20 vehicles and 5 secondary structures	Omit	This was probably a business, not a residence. There were only a few businesses in the data set; they were omitted. It is assumed that businesses differ from residences in construction and zoning.
Var = *Remarks*	Text field for General Comments	Used as a corroborator during the data cleansing phase of the project, but omitted from regression analysis.	The handwritten notes of the field staff were very useful for corroborating other variables, but relatively unworkable for regression analysis.
Var = *Deck/Porch*	Text field for Deck/Porch description. Many of the fields were left blank.	Created 1 variable indicating the existence of a deck/porch and 2 interaction variables indicating if the deck was unenclosed or made of nonwood material.	Most of the text fields contained 3 types of information about decks/porches. This information was reformatted as 3 binary variables. A blank field was interpreted as a structure with no porch/deck.
Var = *Type of H2O Supply*	Numerically coded field: 1 = Municipal 2 = Private 3 = Well 4 = Other Most of the entries were left blank for unknown reasons	Omit	The high number of blank entries for this variable might be indicative of bias, e.g. water tanks seem to be frequently reported as an H2O source. This might have been because a tank was on the parcel and much easier to identify than other types of H2O sources. One should compare this to the *Deck/Porch* variable; both variables had many blank entries. However, almost all houses have an H2O source, but many houses don't have Deck/Porches.
Var = *Square Feet*	Almost all of the entries from the Grand Prix fire were omitted. This is likely the result of using different data collection forms across fire regions.	Omit	The assumptions that are required to employ methods that estimate missing values in terms of the values that are available aren't satisfied.

3. Proportion of observations in the data set corresponding to particular explanatory variables listed.

Variable Name	Percentage
Total Loss	83
Mobile	8.7
MotorTrav	3.1
Outbuilding	20.9
ManyVehicles	2.6
DefSpace	15.3
DefAction	3.2
ClassA	2.6
ClassB	1.1
Wood	0.9
CompShing	54.2
TarGrav	1.4
Masonry	14.1
AsphShing	2.0
Metal	6.8
Landscape	6.
HeavyOrn	7.5
Grassland	7.2
HeavyBrush	23.1
nonConifer	7.1
Conifer	46.8
Stucco	28.7
Wood	43.7
Metal	5.7
Masonry	6.4
T111	1.4
Deck	11.1
Unenclosed	1.8
nonWood	1.4
DoublePane	11.0
Tempered	0.8
AlumReVinyl	1.0
Alum	29.4
Vinyl	2.1
Wood	16.3
Skylight	0.68
Short	3.5
Open	5.8
Boxed	5.7
Wood	5.0

4. Details and Further comments on Analysis

Because the goal of this analysis was to generalize findings by applying results to a larger group or population, caution is advised in that to the knowledge of the authors' this is the first study of its type to have been carried out. It seems intuitively reasonable to generalize these findings to structures located in the Urban\Wildland Interface in Southern California. However, less can be said about generalizing these findings to regions with different climate, building codes, vegetation, topography, fire fighting capacity, etc. The results presented here should be treated as a pilot study.

The overall ability to extend such results to such a population is derived from being able to define that population concisely and then to select a sample from that population at random. We are then able to present the results of the analysis in terms of what can be expected if we were to repeat the process using the same population. Unfortunately, as is often the case, it is not entirely clear what the population should be in this case or whether it is reasonable to assume that the sample at hand was "randomized by nature". For example, the fire impact was more intense in some regions. If the building codes in these regions dictate composite roofs and stucco walls, and if the observations from this region represent almost all of the observations in the sample that have composite roofs and stucco walls, the results of analysis will be biased in the sense that they don't reflect the "average" fire resistance of the structure type. However, note that a bias of this type may be recognized as such if presented to an expert who is familiar with the fuel types and fuel loads in that region. Expert feedback is particularly useful when the factors and mechanisms of ignition are well known and few.

The fact that fire professionals have relied on this information for years in order to assure their safety and to fight fires justifies the use of these factors in the analysis presented here. (For detailed expositions on this subject, see references by Cox[1], Deming[2], and Freedman[3].)

Overarching aspects affecting the analysis have been discussed in the text or above. What follows are the technical details of the analysis; the caveats of this process were covered in the previous section.

The choice in regression technology was determined, in part, by the data format and the subject matter. As mentioned before, the original data set was transformed into a data set of binary variables. Inevitably, this resulted in some aggregation of information. The potential for over-aggregating the information exists. For example, because there were so many structures that were characterized as a "total loss" (78.9%) and so few characterized as having either "moderate" or "major" damage (5.4%), it might be useful to conceptualize the ignition process as one that either

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[1] Cox D. R, Snell, E. J. (1981). *Applied Statistics: Principles and Examples*. London: Chapman and Hall.

[2] Deming, W. P. (1950). *Some Theory of Sampling*. New York: Dover.

[3] Berk R. A. and Freedman, D. A., Statistical Assumptions as Empirical Commitments. In *Law, Punishment, and Social Control: Essays in Honor of Sheldon Messinger*, 2nd ed. Aldine de Gruyter (2003) pp. 235–54. T. G. Blomberg and S. Cohen, eds.

Freedman, D.A. Sampling. *Encyclopedia of Social Science Research Methods.* Sage Publications (2004) Vol. 3 pp. 986–990. M. Lewis-Beck, A. Bryman, and T. F. Liao, eds.

destroyed structures or left them intact.[2] Also, the nominal scale used ("1 thru 5"), which was intended to indicate the level of structure damage, required that many factors be considered by the data collector in order to assign a damage level; thus it was deemed unreliable.

The categorization of the parcels and structures by the field staff did allows us to "classify" the observations. The observations that correspond to a particular set of features constitute a *covariate class*. In each covariate class a certain number of the observations will be categorized as a "total loss". It is useful to conceptualize the number of observations marked "total loss" per covariate class as being generated by the sum of independent homogenous Bernoulli trials. One major objection to this assumption is that adjacent structures may pose a considerable threat to each other if either is burning, i.e. the outcome of one observation might have considerable influence on others. The indicated sum has a binomial distribution with the same parameter as the one used in the Bernoulli trials. This suggested logistic regression as a possibility for modeling the data.

To start, a saturated model of first degree terms was estimated using the statistical functionality of the programming language R. In particular, glm()was used with family="binomial" as an option. Interaction terms were then included as suggested by the subject matter, e.g. an interaction of defensible space and conifers. A manual recursive process of removing and adding terms helped determine which terms explain the response. Particular attention was paid to the change in p-values and coefficient estimates when a term was added or removed. AIC was used as a measure of goodness of fit of the specified model. Many of the models that seemed to correspond to roughly the same (relatively low) AIC were qualitatively similar, i.e. the direction and magnitude of the coefficients were similar, both relatively and absolutely. At times the subject matter was used to rank the models and differentiate between them. A representative model is included here:

Term	Coefficient	SE	p-value
(Intercept)	1.30	0.25	2.20E-07
Grand Prix Fire	-0.89	0.30	0.003
DefSpace	1.12	0.44	0.011
DefAction	-2.51	0.63	7.00E-05
ClassA (Roof)	-2.53	0.66	0.0001
CompShing (Roof)	0.63	0.30	0.037
TarGrav (Roof)	-1.96	0.98	0.046
Masonry (Roof)	1.19	0.68	0.079
Deck	-1.21	0.39	0.002
DoublePane (Window)	-1.34	0.38	0.0005
Wood (Window Frame)	1.45	0.67	0.030
Alum (Window Frame)	1.28	0.42	0.003
Short (Eave)	-1.77	0.50	0.0004
HeavyBrush	1.08	0.33	0.001
Conifer	1.41	0.35	8.52E-05
DefSpace:T111 (Interaction)	-3.71	1.42	0.009
DefSpace:Conifer (Interaction)	-1.82	0.92	0.050
DefSpace:Grassland (Interaction)	-1.94	0.98	0.048

Table 1 – Coefficient estimates for logistic regression. AIC = 516.1 w/ df=865

The table shown in the text including errors of estimate vs. observed numbers of losses follows. Note that the note following discusses the merits of using a percentage to describe the error of the estimate given the [sometimes] limited numbers of observations for a given covariate sets of data:

Covariate Class	**Predicted # "Total Loss"**	**Actual # "Total Loss"**	**Error**
Mobile & **DefSpace** & HeavyOrn	46.8	49	-2.11
CompShing & **Conifer** & WoodWall & **Alum**	37.6	37	0.63
CompShing & **Conifer** & WoodWall	18.4	17	1.36
Conifer	7.5	7	0.50
CompShing & **HeavyBrush** & WoodWall & **Alum**	5.9	6	-0.08
Paradise & MetalRoof & MetalWall	3.1	4	-0.85
CompShing & **HeavyBrush** & WoodWall & **Masonry** & **Alum**	2.0	2	0.00
GP & **Short** & Boxed	0.4	1	-0.59
MotorTrav & Grassland & **Conifer**	0.9	1	-0.06
GP & **Short** & Boxed	0.4	1	-0.59
DefSpace & **DefAction** & **ClassA** & **CompShing** & **HeavyBrush** & Stucco & **Deck** & **DoublePane** & Vinyl & Open & WoodEave	0.03	0	0.03

Table 2 – A comparison of predicted and actual values. Note that the actual values can only be integers but the predicted values are often fractions. As a result, the errors for each covariate class are often an 'artifact of the data'. If we used *percent error* to assess the model fit we could be misled, e.g. the *percent error* for the covariate class '**GP** & **Short** & Boxed' is 59%. However, many would agree that in the context of this problem 0.4 is a suitable estimate of 1.0.